PUBLIC DOCUMENT No. 31

MASSACHUSETTS AGRICULTURAL COLLEGE

ANNUAL REPORT

OF

THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

PARTS I AND II

1920

PUBLIC DOCUMENT No. 31

MASSACHUSETTS AGRICULTURAL COLLEGE

THIRTY-THIRD ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

PARTS I AND II

Publication of this Document
approved by the
Supervisor of Administration.

THIRTY-THIRD ANNUAL REPORT

OF THE

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

PART I

REPORT OF THE DIRECTOR AND OTHER OFFICERS

PART II

DETAILED REPORT OF THE EXPERIMENT STATION

BEING PARTS III AND IV OF THE FIFTY-EIGHTH ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL COLLEGE

A RECORD OF THE THIRTY-EIGHTH YEAR FROM THE FOUNDING OF THE STATE AGRICULTURAL EXPERIMENT STATION

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Massachusetts Agricultural Experiment Station.

OFFICERS AND STAFF.

COMMITTEE.

STATION STAFF.

Administration.

Sidney B. Haskell, B.Sc., *Director.*[1]
Fred W. Morse, M.Sc., *Acting Director.*[2]
Joseph B. Lindsey, Ph.D., *Vice-Director.*
Fred C. Kenney, *Treasurer.*
Charles R. Green, B.Agr., *Librarian.*
Mrs. Lucia G. Church, *Secretary to the Director.*
Miss F. Ethel Felton, A.B., *Clerk and Editorial Assistant.*

Agricultural Economics.

Alexander E. Cance, Ph.D., *Professor.*
Miss Lorian P. Jefferson, M.A., *Assistant Research Professor.*[3]

Agriculture.

William P. Brooks, Ph.D., *Consulting Agriculturist.*
Edwin F. Gaskill, B.Sc., *Assistant Research Professor.*
Robert L. Coffin, *Investigator.*

Botany.

A. Vincent Osmun, M.Sc., *Professor.*
George H. Chapman, Ph.D., *Research Professor.*[4]
Paul J. Anderson, Ph.D., *Professor.*
Orton L. Clark, B.Sc., *Assistant Professor.*
Webster S. Krout, M.A., *Assistant Research Professor.*
Miss Marguerite G. Ickis, M.A., *Curator.*
Alyn S. Ball, *Laboratory Assistant.*
Miss Ellen L. Welch, A.B., *Clerk.*[5]
Miss Gladys I. Miner, *Stenographer.*[6]

Cranberry Substation.

Henry J. Franklin, Ph.D., *Research Professor in Charge.*

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1 Appointed July 1, 1920.
2 Until July 1, 1920.
3 Appointed June 1, 1920.
4 Absent on leave, Jan. 1 to March 15, 1920.
5 Resigned Nov. 5, 1920.
6 Appointed Oct. 1, 1920.

Entomology.	Henry T. Fernald, Ph.D., *Professor.* Arthur I. Bourne, A.B., *Investigator.* Harlan N. Worthley, B.Sc., *Investigator.*[1] Miss Bridie E. O'Donnell, *Stenographer.*
Horticulture.	Frank A. Waugh, M.Sc., *Head, Division of Horticulture.* Fred C. Sears, M.Sc., *Professor of Pomology.* Jacob K. Shaw, Ph.D., *Research Professor of Pomology.*[2] Harold F. Tompson, B.Sc., *In Charge of Market-Garden Field Station.* Walter W. Chenoweth, M.Sc., *Professor of Horticultural Manufactures.* Miss Ethelyn Streeter, *Stenographer.*
Meteorology.	John E. Ostrander, A.M., C.E., *Meteorologist.*
Microbiology.	Charles E. Marshall, Ph.D., *Professor.* Arao Itano, Ph.D., *Assistant Professor.*
Plant and Animal Chemistry.	Joseph B. Lindsey, Ph.D., *Chemist.* Edward B. Holland, Ph.D., *Research Professor.* Fred W. Morse, M.Sc., *Research Professor.* Henri D. Haskins, B.Sc., *Official Chemist, Fertilizer Control.* Philip H. Smith, M.Sc., *Official Chemist, Feed Control.* Lewell S. Walker, B.Sc., *Assistant Official Chemist, Fertilizer Control.* Carleton P. Jones, M.Sc., *Assistant Research Professor.* Carlos L. Beals, M.Sc., *Assistant Research Professor.* Arthur M. Clarke, A.B., *Assistant Chemist.*[3] Miss Anne C. Messer, B.A., *Investigator.* Miss Ethel M. Bradley, B.A., *Analyst.* Raymond W. Swift, B.Sc., *Analyst.*[4] James T. Howard, *Inspector.* Harry L. Allen, *Laboratory Assistant.* James R. Alcock, *Assistant in Animal Nutrition.* Miss Rebecca L. Mellor, *Stenographer.* Miss Cora B. Grover, *Stenographer, Control Service.*
Poultry Husbandry.	John C. Graham, B.Sc., *Professor.*[5] Loyal F. Payne, B.Sc., *Acting Head of Department.*[6] Hubert D. Goodale, Ph.D., *Research Professor.* Miss Ruby Sanborn, *Clerk.* Miss Doris Tower, *Stenographer.*
Veterinary Science.	James B. Paige, B.Sc., D.V.S., *Professor.* G. Edward Gage, Ph.D., *Professor of Animal Pathology.* Thomas G. Hull, Ph.D., *Assistant.*[7] John B. Lentz, V.M.D., *Assistant Research Professor.*[8]

[1] Appointed July 1, 1920.
[2] Reappointed June 1, 1920.
[3] Resigned Sept. 30, 1920.
[4] Appointed Oct. 1, 1920.
[5] Reinstated April 1, 1920, after leave of absence.
[6] Until April 1, 1920.
[7] Temporary appointment, resigned Jan. 10, 1920.
[8] Temporary appointment, Feb. 4 to May 31, 1920; permanent appointment, June 1, 1920.

REPORT OF THE DIRECTOR.

SIDNEY B. HASKELL.

The work of the Experiment Station this past year has been affected by many of the personal factors which so influenced work in other major subdivisions of the institution. Chief among these factors has been that of uncertainty as to the future, brought about by delay in securing the salary adjustment necessary to make the rate of pay somewhat more nearly comparable to the increased cost of living. This delay produced a feeling of uneasiness absolutely inimical to the good conduct of research work. Despite this fact, there have been but few changes in staff membership, these being as follows: —

Arthur M. Clarke resigned the position of assistant chemist on Sept. 30, 1920, and was succeeded by Mr. Raymond W. Swift, a graduate of the College with the class of 1920.

Dr. Thomas G. Hull, assistant in the Department of Veterinary Science, resigned Jan. 10, 1920. Dr. John B. Lentz, who resigned Sept. 18, 1919, having been in the service of the institution about three years, was reappointed February 4, as assistant research professor in the Department of Veterinary Science.

Prof. Fred W. Morse, who had been serving as acting director since the retirement of Dr. William P. Brooks, in March, 1918, resumed his work as research professor of chemistry on July 1.

Dr. Jacob G. Shaw was reappointed to the position of research professor of pomology, beginning June 1, 1920. Dr. Shaw comes back to this institution from service as head of the Department of Horticulture in the University of West Virginia.

Miss Lorian P. Jefferson, formerly assistant professor in the Division of Rural Social Science in the College, was appointed assistant research professor in agricultural economics, effective June 1.

Miss Ellen L. Welch, clerk in the Department of Botany, resigned Nov. 5, 1920, her position being taken by Miss Gladys I. Miner.

Changes in Departmental Organization.

With the development of larger bodies of knowledge in technical agricultural subjects has come increasing specialization. This has rendered necessary certain changes in organization in order that the work of the Experiment Station might conform to the departmental organization of the College. During the year just past the trustees approved the following changes, to become effective Dec. 1, 1920: —

Department of Horticulture, first recognized as an Experiment Station department in 1888, when the Hatch Experiment Station was organized, to be discontinued.

In place of the Department of Horticulture the following departments to be organized: —

Department of Pomology, with Prof. Fred C. Sears, head.

Department of Horticultural Manufactures, under the leadership of Prof. Walter W. Chenoweth.

Department of Market Gardening, and Market-Garden Field Station, under the leadership of Prof. H. F. Tompson.

The above changes in organization indicate no change in scope of work.

Publications of the Year.

The sole avenue through which the Experiment Station work can be taken at once to the people of the State lies in the publication of pamphlets and bulletins. Below is presented a list showing the publications of the year. Unfortunately, appropriations for publications were so small as to make it impossible to complete publication of all manuscripts which have been submitted. It is hoped that a larger sum will be available for the coming year.

Publications issued During 1920.

Annual Report.

Thirty-second annual report: —

Part I. Report of Director and Other Officers; 48 pages.

Part II. Detailed Report of the Experiment Station; 258 pages (being Bulletins Nos. 189–194).

Combined Contents and Index, Parts I and II; 20 pages.

Bulletins.

No. 195. Tobacco Investigations: Progress Report, by G. H. Chapman; 38 pages.

No. 196. Methods of Applying Manure, by Wm. P. Brooks; 22 pages.

No. 197. Nutritive Value of Cattle Feeds. 1. Velvet Bean Feed for Farm Stock, by J. B. Lindsey and C. L. Beals; 14 pages.

No. 198. Studies of Cranberries during Storage; 18 pages.
Chemical Studies, by F. W. Morse and C. P. Jones.
Fungi Studies, by B. A. Rudolph and H. J. Franklin.

No. 199. Broodiness in Domestic Fowl: Data concerning its Inheritance in the Rhode Island Red Breed, by H. D. Goodale, Ruby Sanborn and Donald White; 24 pages.

No. 200. Nutritive Value of Cattle Feeds. 2. Oat By-Products for Farm Stock, by J. B. Lindsey and C. L. Beals; 20 pages.

Bulletins, Popular Edition.

No. 200. Nutritive Value of Cattle Feeds. 2. Oat By-Products for Farm Stock, by J. B. Lindsey and C. L. Beals; 10 pages.

Bulletins, Control Series.

No. 13. Inspection of Commercial Feedstuffs, by Philip H. Smith and Ethel M. Bradley; 27 pages.

No. 14. Inspection of Commercial Fertilizers, by H. D. Haskins, L. W. Walker and A. M. Clarke; 92 pages.

Meteorological Reports.

Nos. 373–384, inclusive, 4 pages each.

The Project System.

An important development of the year is the attempt to organize all Experiment Station work on a definite project basis. This change is peculiarly necessary at the present time, owing to the fact that agricultural research has to a great degree passed beyond the simple "test" phase of its work. The problems which must now be undertaken are those which require in a great degree co-ordination between departments. Especially is this true of the work of the technical departments, for without exception these departments must make use of the fundamental sciences as tools in their investigation. It is neither practicable nor desirable, however, for each of these technical departments to duplicate the scientific equipment of

the fundamental scientific departments. Seemingly the only way in which effective co-operation can be brought about lies in securing the necessary co-ordinated study.

This work of project organization is not yet completed. The following, however, shows the projects either now under way, or so organized as to be under way in the very near future: —

Plant Nutrition — Comparative Fertilizer and Lime Tests.

Comparison of nitrogenous fertilizers; comparison of sulfate and muriate of potash; comparison of potash carriers; comparison of phosphate carriers; effects of plant foods alone and in combination; use of chemicals in supplementing stable manure for garden crops; orchard fertilization; experiments with Barium-Phosphate; relative value of different sources of lime; high potash *versus* high phosphoric acid fertilizers; study of bacterized peat; manure economy tests.

Plant Nutrition — Chemical and Biological Investigations.

Chemical effects of muriate and sulfate of potash; lime absorption and acidity of Field A; soil fertility as influenced by microorganisms.

Plant Adaptation — Variety Tests.

Variety tests of fruits; asparagus variety test; limited variety test of vegetables; observations of summer forage crops.

Plant Physiology and Heredity.

Study of optimum conditions of light for plant response; the interrelation of stock and scion in apples; the genetic composition of peaches; study of tree characters of fruit varieties; study of the life processes of the strawberry.

Cultural Studies.

Cranberry bog management; cranberry bog weeds; blueberry culture; experiments in pruning apples; study of production with greenhouse lettuce and cucumbers.

Plant Protection — Insects.

Studies of insect outbreaks in various localities; limits of insect pests in Massachusetts; the number of broods of the codling moth in a year; dates of hatching of scale insects, and fixing dates for spraying such insects; insects affecting the cranberry; control of the onion maggot; control of the squash-vine borer; burning of foliage by insecticides; control of the squash bug; insect control on market-garden crops; study of the chemistry of arsenical insecticides.

Plant Protection — Fungous Troubles.

Investigation of onion diseases; experimental spraying for control of cucumber mildew under glass; methods for controlling lettuce drop; fungous diseases of cranberries (co-operative with the Bureau of Plant Industry, United States Department of Agriculture).

Plant Studies — Miscellaneous.

Study of tobacco sickness and tobacco-sick soils; studies of cranberry storage and shipping conditions.

Animal Nutrition.

Comparative feeding tests and feeding trials of new materials; record of the Station herd; digestion experiments with sheep; a study of rations for horses.

Animal Physiology.

A study of the chemistry of butter fat, etc.; determination of the mode of inheritance of various characters in poultry.

Animal Pathology.

Methods of diagnosis of bacillary white diarrhea; elimination of disease in poultry; study and control of poultry diseases in College and Station flocks; study and control of bovine abortion; study of hog cholera and the use of serum.

Meteorological Studies.

Weather observations, with especial attention to frost protection; areas in which immunity from early and late frosts may be expected, and the consequent effect on selection of crops; general weather observations.

Studies in Food Distribution.

Methods and costs of distribution of tobacco and onions; study of consumers' co-operative associations (in co-operation with the Bureau of Markets, United States Department of Agriculture).

Studies in Food Preservation.

Canning investigations.

Progress in some of these investigations is handicapped by a shortage of land. This condition is due primarily to the encroachment of buildings on the old Experiment Station grounds, but in addition is due to the fact that land once used for certain types of experiment is rendered useless for other kinds of experiments for long periods of years. Therefore, while it is true that several of the present field experiments had best be brought to a close, yet the land involved will not become immediately available for other investigations. It is therefore hoped that the projects now in the hands of the trustees for the purchase of the Brooks Farm and of the Tuxbury land will receive the support of the Legislature.

In this connection it should be stated that the time is coming when the Experiment Station must branch out and undertake thoroughgoing work in other sections of the State. A start in this direction was made about ten years ago when the Cranberry Station was first organized. The success of this station

has been so marked as to gain the unqualified support of cranberry growers. The Market-Garden Field Station was later established at North Lexington, although in the beginning not on an experimental basis. The next step, logically, is to go west of the Connecticut and establish an experimental substation in the hills of western Hampshire, Franklin or Hampden county. Many technical problems of production must be solved before these hill farms can be brought back to their old-time productive condition.

Additional Assistants.

An unexpected result of the organization and development of the county farm bureaus has been the increased demand made on the Experiment Station for service in investigating problems affecting agriculture. The inability of the Station to meet these demands is causing criticism. While there is no doubt that much of this criticism arises from ignorance rather than knowledge, yet the fact is that the farmers of the State, as represented by their county agricultural agents, are more eager than ever for knowledge and for facts. The Experiment Station cannot ignore these demands, and is making every effort in its power to meet them. At present, however, investigations under way are so numerous and so important as to make it almost imperative that we secure additional assistants to give attention to the new problems which are constantly arising. Those needed in the immediate future are as follows: —

Assistant to the Director.
Clerk and graduate assistant, Department of Agricultural Economics.
Assistant research professor, Department of Botany.
Assistant research professor, Department of Horticultural Manufactures.
Assistant in experimental market gardening, Market-Garden Field Station.
Assistant in experimental pomology and graduate assistant, Department of Pomology.
Assistant research professor and two graduate assistants, Department of Microbiology.
Poultry pathologist,[1] Department of Veterinary Science.
Research professor and laboratory assistant, Department of Farm Management.
Research professor, Department of Rural Sociology.
Poultry pathologist[1] and collector of blood samples, Poultry Disease Law.

[1] One-half time.

ACKNOWLEDGMENT.

In conclusion I wish to acknowledge the hearty and loyal co-operation accorded me by the different members of the Experiment Station staff. I believe that the time which is usually lost through change in any administrative organization will be somewhat decreased through the services thus freely given. Particularly I wish to express my appreciation of the co-operation given me by Dr. William P. Brooks, formerly director of the Station and now consulting agriculturist; Prof. F. W. Morse, formerly acting director; and Dr. J. B. Lindsey, vice-director of the Station. All of these men have spared no pains in placing at my disposal all information needed in prosecuting the work.

REPORT OF THE TREASURER.

ANNUAL REPORT

OF FRED C. KENNEY, TREASURER OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION OF THE MASSACHUSETTS AGRICULTURAL COLLEGE, FOR THE YEAR ENDING JUNE 30, 1920.

United States Appropriations, 1919–20.

		Hatch Fund.	Adams Fund.
Dr.			
To receipts from the Treasurer of the United States, as per appropriations for fiscal year ended June 30, 1921, under acts of Congress approved March 2, 1887, and March 16, 1906,		$15,000 00	$15,000 00
Cr.			
Adams: —			
By salaries,	$14,448 31		
labor,	272 00		
chemicals and laboratory supplies,	4 58		
seeds, plants and sundry supplies,	58 89		
fertilizers,	216 22		
	$15,000 00		15,000 00
Hatch: —			
By salaries,	$14,081 50		
labor,	918 50		
	$15,000 00	15,000 00	

State Appropriations.

Cash balance brought forward from last fiscal year,	$21,992 62
Cash received from State Treasurer,	55,875 80
fees,	155 77
sales,	5,530 79
miscellaneous,	2,022 02
	$85,577 00

Cash paid for salaries,	$26,206 90
labor,	14,591 80
publications,	3,182 72
postage and stationery,	1,387 81
freight and express,	303 45
heat, light, water and power,	353 52
chemicals and laboratory supplies,	945 99
seeds, plants and sundry supplies,	1,659 57
fertilizer,	763 08
feeding stuffs,	1,007 98
library,	873 08
tools, machinery and appliances,	942 87
furniture and fixtures,	190 55
scientific apparatus and specimens,	198 12
live stock,	15 00
traveling expenses,	2,091 49
contingent expenses,	37 65
buildings and land,	1,124 22
Remitted to State Treasurer,	29,701 20
Total,	$85,577 00

REPORT OF THE DEPARTMENT OF AGRICULTURAL ECONOMICS.

ALEXANDER E. CANCE.

The research work of the department has been carried on along three lines: —

Consumers' Co-operation in Massachusetts. — For about two months the department co-operated with the Federal Bureau of Markets in a brief study of consumers' co-operation in Massachusetts. Since the period given to this work was short, it was impossible to do more than study types of co-operative enterprises among consumers, no effort being made to arrive at the total membership in such organizations or their total volume of business.

The forms of so-called co-operative consumers' organizations found in the State were: —

(*a*) Buying clubs, — unincorporated groups which buy supplies together but keep no stock of goods on hand and distribute orders by the easiest method possible.

(*b*) Stores, organized, owned and operated by the consumers, each member owning so much stock in the business and having a vote in all business matters. These are incorporated groups, some few of which have been doing business for a number of years.

(*c*) So-called co-operative stores: in reality stores maintained for the employees of a manufacturing company by the company itself. At these stores goods are offered at less than the price asked at neighboring retail stores, the company carrying all the overhead expenses of rent, heat, light and clerk hire. One firm frankly acknowledged that they expected to lose $10,000 a year on the enterprise. On the other hand, another store was found which was started by the firm for its

employees, but which has gradually passed into the hands of the employees, the firm now having nothing to do with the conduct of the store, and supplying nothing but the quarters which it occupies.

This brief study revealed an increasing interest in co-operation among consumers. Stores are being opened by all classes, but chiefly among factory employees. Labor leaders are interested in the movement, which is especially strong among foreigners, particularly the Italians and Finns, the latter having sixteen stores of various kinds in the State.

A number of requests were received for assistance in securing farm products for these consumers' associations. These were turned over to the Extension professor of the department, who has taken steps to render the assistance asked.

Farm Ownership in Massachusetts. — The second line of research which has been carried on throughout the year is a study of farm ownership in Massachusetts. A questionnaire was prepared and has been filled out by 650 farmers of the State, some of the schedules being secured by mail and some by personal visits. The county agents of several counties have rendered most valuable assistance in this matter. Although the study is yet incomplete, some interesting facts with regard to the steps to farm ownership are already in hand. It is expected that a bulletin embodying the results of this study will be ready for publication within the year.

Onion Supply and Distribution in the Connecticut Valley. — The department is bringing up to date the data on onion supply and distribution in the Connecticut valley previously published in Bulletin No. 169. The supply, weekly shipments, destinations, prices, storage stocks and recent developments in preparation and marketing are the principal data studies. It is the purpose of the department to publish during 1921 a supplement to Bulletin No. 169 embodying these new data.

Proposed Research Work for the Coming Year.

Supply and Distribution of Connecticut Valley Tobacco. — It is proposed to gather similar information with reference to the supply and distribution of cigar leaf tobacco in the Connecticut valley to supplement Bulletin No. 193 published in 1919.

This bulletin, entitled "The Supply and Distribution of Connecticut Valley Cigar-leaf Tobacco," was prepared by Samuel H. DeVault, at that time assistant in the department. The bulletin has been of such service to both growers and dealers that it is deemed advisable to bring up to date the information therein presented.

Local Balance of Trade. — The line of investigation on which the emphasis will be laid, with the approval of the trustees, is a study of the local balance of trade in certain markets. Specifically it is suggested that this study be made in Fitchburg, Lynn and Lawrence, with perhaps some others to be added later. The products to be considered will be those which cannot be grown locally; products which might profitably be grown but for some reason are not (for this portion of the study the assistance of various members of the Division of Agriculture will be enlisted); products which are grown locally but not in sufficient quantity to supply the local market; products grown locally in quantity sufficient to supply the local market with a surplus for export; products which are exported with shipments returned to the local market or duplicated by shipments from outside areas.

Clerical assistance is much needed in order to expedite the work. At present the only clerical help available is that assigned to the instructional staff. The work demands a competent clerk capable of doing stenographic work and tabulations, and of looking up statistical data.

REPORT OF THE DEPARTMENT OF AGRICULTURE.

E. F. GASKILL.

The work of the Agricultural Department during the past year has progressed along the same general lines as heretofore. A large part of the work has had to do with a study of different phases of the problem of soil fertility, which has necessitated the care and management of a large number of field plots. Many of these plots have received a continuous treatment since the organization of the Experiment Station in 1888, while some, owing to the disappearance of certain fertilizer materials from the market during the war and the scarcity of others, have undergone material changes and rearrangements. Despite these changes there are several significant facts brought out by the crop yields of the season just past.

Field A, or the Nitrogen Field. — Three plots on Field A (the nitrogen field) gave an average crop of hay and rowen of slightly more than 3,100 pounds per acre. This yield, while not large, was significant in that these plots had received no nitrogen in either fertilizer or manure for a period of thirty years. The records on this series of plots are becoming increasingly valuable year by year, indicating a distinct gain of nitrogen through the growth of leguminous crops. Another record from this field of more than incidental value is the fact that although a mixture of grasses and clovers was sown last year, this year's crop was practically free of clovers except on the no-nitrogen plots. Once again the fact that large amounts of commercial nitrogen are somewhat antagonistic to the growth of clovers is strikingly demonstrated.

The Response of Crops to Potash. — The response of crops to potash when used on different types of soil is brought out by a

comparison of the yields on two of the Experiment Station fields. The soil on the South Soil Test is considered a light loam, while that on Field G is a heavy, silt loam. In both fields there are plots to which no potash has been applied for years, but which have received annual applications of nitrogen and phosphoric acid. The rates of application of these plant-food elements per acre are shown in the following table: —

Field.	Total Nitrogen (Pounds).	Total Phosphoric Acid (Pounds).	Total Potash (Pounds).
South Soil Test,	About 25 (as nitrate),	51 (from acid phosphate),	80
Field G,	39 (from nitrate),	57½ (from acid phosphate),	135
	20 (from tankage),	30 (from tankage),	

The increase due to the use of potash on these fields for different crops over a long term of years is shown in the following table: —

Crop.	South Soil Test.		Field G.	
	Number of Years grown.	Increase per Acre due to Potash.	Number of Years grown.	Increase per Acre due to Potash.
Corn,	9	32½ bushels,	3	½ bushel.
Soy beans,	1	12.8 bushels,	4	¼ bushel.
Mixed hay,	6	738½ pounds,	3	1,735½ pounds.[1]
Rowen,	4	405 pounds,	–	–
Clover,	–	–	2	598 pounds.
Potatoes,	–	–	5	54.1 bushels.

[1] Includes hay and rowen.

These two fields are scarcely more than 200 yards apart. The soil survey map published by the Bureau of Soils, United States Department of Agriculture, classifies them together. Were the land still used as a farm instead of for experimental purposes, the two areas would probably be thrown together in the same field, and put to the same uses. Yet we have one part where without potash corn cannot grow; another part where the use of liberal quantities of fertilizer potash makes

scarcely a perceptible difference in the yield of corn. So varied are our New England soils!

The Effect of Nitrogen, Phosphoric Acid and Potash on Corn and Grass. — An opportunity was offered during the past two seasons to study the same crop on three of our experimental fields, — namely, the nitrogen field, the potash field and the phosphate field. During 1919 these three fields were in corn. In one case the limiting factor was nitrogen, in another potash and in another phosphoric acid. On all of these fields there were certain plots that have received incomplete mixtures; for example, the check plots on the potash field received no potash. The rates of application of the several plant-food elements per acre are shown in the following table: —

FIELD.	Total Nitrogen (Pounds).	Total Phosphoric Acid (Pounds).	Total Potash (Pounds).
Nitrogen Field,	45,	80 (from acid phosphate),	125
Potash Field,	39 (from nitrate), 20 (from tankage),	57½ (from acid phosphate), 30 (from tankage),	135
Phosphate Field,	56 (from nitrate), 20 (from ammonia), 14.6 (from organic nitrogen),	96,	150

The yields of hard corn follow, the figures representing bushels per acre: —

FIELD.	Incomplete Fertilizer or Check.	Complete Fertilizer.	Gain of Complete over Incomplete.
Nitrogen Field,	48.7 (P+K)	66.3	17.6
Potash Field,	49.6 (N+P)	64.3	14.7
Phosphate Field,	57.6 (N+K)	65.0	7.4

The significance of these figures lies in their uniformity. The average product of complete fertilizer treatment on all three fields is practically the same.

During the past season these same fields were in grass and clover, the seed mixture sown being the same in all cases. The

hay yields on these fields were as follows, the figures representing pounds per acre: —

Field.	Incomplete Fertilizer or Check.	Complete Fertilizer.	Gain of Complete over Incomplete.
Nitrogen Field, ...	3,148.3	5,163.4	2,015.1
Potash Field, ...	5,944.0	6,210.3	266.3
Phosphate Field, ...	7,060.0	7,902.4	842.4

Comparison of the grass yields of this year with the corn yields of last year is illuminating. Last year the complete fertilizer treatment, varied as it was on the different soils, gave uniform yields of corn. This year the same treatment gave rather diverse yields of hay. All of this happened, however, within a section of land which might well be compassed by the boundaries of a 5-acre lot. Very evidently the peculiar soil conditions in New England make very difficult the drawing of generalizations from fertility field experiments.

REPORT OF THE DEPARTMENT OF BOTANY.

A. VINCENT OSMUN.

The work of the Department of Botany during the last year has not deviated in any important respect from that previously reported. Research work, the normal function of the Experiment Station, continued to engage the major attention of the staff. While no new projects were started, certain changes and additions were made in some of those under way.

Report on Project Work.

The report on project work is one of progress. Some lines of investigation are essentially completed. Several bulletins and technical papers are in course of preparation by members of the staff, and will be presented for publication as speedily as other work will permit.

Tobacco Investigations. — Tobacco investigations, under the leadership of Dr. G. H. Chapman, have so developed that it has become advisable to discontinue the plots located on privately owned farms during the last four years. The project has been reorganized, and in the future plots will be conducted on College-owned land controlled by the Station. A progress report on the project was published in March of the present year as Bulletin No. 195.

Investigation of Onion Diseases. — Investigation of onion smut under the project on onion diseases has continued, with results on the field plots confirmatory of those previously obtained. A large amount of painstaking work on the morphology and life history of the onion smut fungus, *Urocystis cepulæ*, has been carried on by Dr. P. J. Anderson, who expects to publish a technical paper on these phases of the investigation during the next year.

Optimum Conditions of Light for Plant Response. — Prof. O. L. Clark has continued to accumulate experimental data in his study of optimum light requirements of plants. That phase of the work embracing study of the influence of different light intensities on plants grown under cloth of different meshes has been discontinued after several years of field tests. A new feature of this work now being planned will deal with the influence of ultra-violet light on plants.

Plant Diseases of the Year.

While the plant diseases coming under our observation were as numerous and varied as in almost any other year, few new or unusual troubles were among them.

Tobacco. — A bacterial disease of tobacco, known in the South as wildfire, was reported for the first time in this State, though there is evidence to support the belief that it was present at least two years earlier. During the curing and fermentation season for tobacco, the weather conditions favored development of such troubles as pole-sweat, stem-rot, canker and moldy or musty tobacco. Considerable loss ensued, and there were many calls for assistance. An Extension bulletin, entitled "Curing and Fermentation Troubles of Tobacco," and an Extension circular on "Tobacco Wildfire," were prepared by Dr. Chapman.

Tomato. — Late in September, Septoria leaf-spot of tomato, caused by *Septoria lycopersici* Speg., was discovered in a small garden in Amherst where it had caused severe defoliation of the vines. The disease previously has been noted on two occasions in greenhouses of the State, but this is the first report of its occurrence out of doors in Massachusetts. In the Middle Atlantic States this disease causes large losses, and is rated as the most serious disease of the tomato in that region. Should it gain a foothold in this State it might become a problem of considerable economic importance.

Carrot. — What appears to be a new disease of the carrot was first called to our attention in 1918 at the Market-Garden Field Station by Prof. H. F. Tompson. The disease seems to be very destructive at times, and while it received some attention in 1919 and 1920, it is deserving of careful investigation, and

will be made the subject of a project. Its cause has not been determined, but it appears to be of fungous origin.

Eggplant. — In 1919 a disease of eggplant, evidenced by wilting and death of the entire plant, was reported from the market-garden sections of the State. One large grower lost a large part of his crop. Preliminary investigation failed to establish definitely the cause of the trouble, and in the absence of this information the grower was advised to plant in 1920 on new land not previously used for this crop. This was done, with the result that the disease in question appeared in only one row, and it developed that this row — the only one of the 1920 planting — was located on a section of the land where the disease occurred in 1919. During the summer Mr. Krout definitely determined the cause of the disease to be a fungus of the genus Verticillium. This disease has been previously reported in other parts of the country, but has had little attention from investigators.

Potato. — Late-blight of potato, always a possible menace to the crop, took a heavy toll the last season. The disease was first observed August 9. Abnormally high humidity throughout August and September, with heavy rainfall in the latter month, furnished conditions highly favorable to the development of the causal fungus. As usual, fields carefully and systematically sprayed with homemade Bordeaux mixture suffered the least. Up to the time of this writing many reports of storage rot due to late-blight have come to the department, and it is probable that the loss from this source will be large.

Apples. — A heavy crop of apples in a season of weather conditions which favored the development of scab and black-rot meant a large initial loss from these diseases in the orchard. The heaviest outbreaks occurred in the eastern part of the State, where early varieties, such as Gravenstein and Yellow Transparent, suffered from black-rot, and McIntosh from scab. In one small area growers estimate that these diseases reduced the value of their crop fully $200,000. The best control measures known have been employed in eastern Massachusetts, and their partial failure indicates that some factor or factors have been overlooked. This points to just one thing, — the need of investigation to determine how these diseases may be

controlled. Because it is apparent that there are unknown factors in the problem, investigational work must start with a careful and detailed study of causal organisms and the relation of environmental conditions to their development. Without this fundamental knowledge the problem of control cannot be attacked with any degree of intelligence. The need of instituting work along this line was pointed out in our last annual report. The experience of the past year has made the need even more urgent. The department is ready to undertake the work whenever financial provisions can be made. This, however, is but one of many lines of investigational work pressing for attention by the Department of Botany. Some of these were referred to in our last report.

Seed Work.

There has been the usual amount of seed work, including germination tests of a variety of vegetable, cereal and grass seeds, and many samples of tobacco and onion seeds; examination of grass seeds to determine purity and the presence of weed seeds; and cleaning and separation of tobacco, onion, lettuce, parsnip and celery seeds.

Extension Work.

Plant disease diagnosis, with the prescribing of remedial measures, demanded more time and attention than in any previous year. The constantly increasing burden of this work tends more and more to interfere with the efficient prosecution of research, and emphasizes the need of an Extension specialist in plant diseases, which has been frequently urged. It is most desirable that this need be met in the near future by the appointment of an Extension plant pathologist to be a member of the staff of the department. The necessity of keeping this type of work within the Department of Botany cannot be pressed too strongly, as it is essential that the department, through the close co-operation of all members of its staff, be constantly and intimately in touch with all the plant disease problems of the State.

REPORT OF THE DEPARTMENT OF CHEMISTRY.

J. B. LINDSEY.

Research Section.

Butter Fat Studies. — Experiments to note the effect of coconut, corn, peanut and soy bean oils upon the chemical character of butter fat have been made during the past year, but owing to the interference of other work the laboratory studies have not been completed. Methods, either direct or indirect, have already been devised for determining with a reasonable degree of accuracy the percentages of the several soluble and insoluble fatty acids of butter fat, and the work of studying food influence is being prosecuted as fast as time will permit.

Insecticides and Fungicides. — A considerable amount of work has been done upon insecticides and fungicides in co-operation with the Department of Entomology, and a number of proprietary products have been examined.

Several poison cases have been investigated for other departments of the College. While this latter is not research work, it was quite necessary and required the services of a specialist.

A method of analysis of lime-sulfur mixtures has been developed which will be submitted for publication in some chemical journal. The method is adapted to the analysis of any of the water-soluble sulfides.

Animal Nutrition. — A thorough study has been made of the nutritive value of oat by-products, — hulls, middlings, and the mixture of the two, known as mill run oat feed, — and the results are now in press.

Digestion studies with sheep have been completed with the

several oat by-products, and also with peanut skins, shells and meal, coffee refuse, coconut meal and cottonseed meal.

Metabolizable energy trials of wheat bran, cottonseed and linseed meals, corn cobs and different varieties of hay have been made with horses. The results in some cases have proved so contradictory that repetitions are now in progress.

Experiments with twelve pigs have just been completed, to note the nutritive and economic value of feeding different amounts of semi-solid and evaporated buttermilk. Because of the high prices of grain as compared with the market price of the pork produced the experiment was not a financial success. The least loss, however, was sustained on the pigs receiving grain alone, followed in succession by those receiving rations composed of grain plus tankage, grain plus powdered buttermilk, and grain plus semi-solid buttermilk.

A demonstrative trial was undertaken with two groups of six pigs each, to observe the value of pasturage and partial soiling as supplements to grain feeding. Because of imperfect control the results were not as satisfactory as desired, but they tend to confirm similar observations elsewhere, which have demonstrated that this method of pork production is well worthy of serious trial by farmers in Massachusetts. It is doubtful, however, in view of the high cost of labor, if much time can be spent in growing forage crops. An alfalfa or clover pasture, or even a fertile grass pasture, could be used, supplemented by grain from self-feeders.

Forage Crops. — Observations in planting soy beans with corn in different ways — mixed together in the drill in the proportion of two-thirds corn and one-third beans, together in the hill, and between the corn hills — were undertaken, but owing to the unsatisfactory character of the bean seed the results were in no way conclusive.

Sudan grass did not prove successful, for in spite of a reasonable amount of seed per acre — 24 pounds broadcast — a very light stand was secured. This condition has repeated itself with us for several years. The seed was sown upon a light, well-drained loam, June 15. Barnyard millet and early amber sorghum have proved more desirable forage crops.

Alfalfa, red clover and sweet clover have each been seeded

together with peas and oats for two successive years. After the peas and oats were cut and removed, these legumes have come on well, and have produced a very satisfactory stand. The rains during the past two years were frequent, which favored their growth. If the season had been dry during the development of the peas and oats, it is doubtful if the legumes would have succeeded by this method of sowing. The clover grew so fast as to enable us to make a cutting in early September.

Respiration of Cranberries. — The study of cranberry respiration was concluded in the early part of the year. The results of the investigation and previous studies of chemical changes during storage have been prepared for publication in a bulletin which is now in press.

Soil Studies. — A striking recurrence on the plots of Field A in 1919, and again this spring, of the toxic effect on plant growth of sulfate of ammonia led to a repetition of some of the research work on the soils of plots 5 and 6, with reference to the presence of soluble salts of manganese, iron and aluminum. Large volumes of water extracts of the soils were prepared and concentrated by evaporation. The residues were analyzed, and amounts of manganese, iron and aluminum were determined by weight. There was found to be present at least 175 parts sulfate of manganese in 1,000,000 parts of dry soil, equivalent to 350 pounds in the upper 8 inches of an acre. This is sufficient to be very poisonous to many kinds of plants. Aluminum was present in much less quantity in the extract, and iron in little more than traces. These results confirm the conclusions of Ruprecht and Morse in previous bulletins of the Experiment Station. A study of the history of the field for thirty-two years has shown that injury on the plots receiving sulfate of ammonia has been most marked in seasons when droughts have occurred in the early summer. The addition of lime to the soil prevents the injury by promoting the formation of sulfate of lime instead of the other salts. Examination of limed soils from these plots showed much smaller quantities of manganese and aluminum in a soluble form, and larger quantities of lime.

Fertilizer Section.

Fertilizer Inspection. — During the season of 1920, 98 manufacturers, importers and dealers have secured certificates for the sale of 583 brands of fertilizer, fertilizing materials and agricultural limes. In the year's inspection, 7,403 tons of fertilizer were sampled, necessitating the sampling of 17,919 sacks; 193 towns were visited; 1,311 samples, representing 492 distinct brands, were drawn from stock found in the possession of 716 different agents or owners; and 738 analyses were made. The table shows the number of brands of the different materials which were registered and sampled, as well as the number of analyses made: —

Material.	Brands registered.	Brands collected.	Number of Analyses.
Complete fertilizers,	292	250	331
Ammoniated superphosphates,	119	95	117
Superphosphate and potash,	6	3	3
Ground bone, tankage and dry ground fish,	54	51	78
Nitrogen compounds,	40	34	100
Phosphoric acid and potash compounds,	45	31	49
Wood ashes,	2	4	36
Lime compounds,	25	24	24
Totals,	583	492	738

A declaration of the tonnage of commercial fertilizers sold in Massachusetts between the dates of Jan. 1, 1920, and July 1, 1920, showed a total of 57,845 tons, divided as follows: —

	Tons
Mixed fertilizers,	47,842
Unmixed fertilizers,	10,003

Full details of the fertilizer inspection work may be found in Bulletin No. 14, Control Series, published in December, 1920.

Miscellaneous Analytical Work. — During the last two months in 1919 and the first three months in 1920 the usual amount of co-operative chemical work was done on problems of the Agricultural Department of the Experiment Station, and on

vegetation experiments conducted by the fertilizer control section.

The fertilizer section has also analyzed 281 different substances sent in by farmers and by the various departments of the Experiment Station. In case of the large number of soil samples which have been examined, the tests made have been largely confined to a determination of the lime absorption capacity of the soils and their content of organic matter. It might be said with reference to the testing of the great variety of fertilizer by-products that an effort has been made, as in the past, to give reliable information in each case as to the best method of utilizing said by-products.

Vegetation Tests. — The following experiments were planned in the fertilizer section, but the details of growing the crops have been left, in all cases, to the Agricultural Department.

A pot experiment comprising 60 pots, with millet as a crop, was conducted to study the availability of the water insoluble organic nitrogen in certain commercial fertilizers found in the 1916 fertilizer inspection work. Many of these samples were considered of suspicious quality so far as their organic nitrogen source was concerned. The purpose of the experiment was to make further studies of the results of laboratory methods as compared with those obtained in vegetation tests. This work was planned several years ago, but due to a scarcity of coal it has not been possible to operate the greenhouse during the winter months, and this season presented the first opportunity for making the test.

An experiment comprising 12 pots, with oats as the crop, was conducted to show the residual effect of peat mixtures with and without commercial bacteria. This was a continuation of a pot experiment begun in 1919.

Another experiment was carried out, using 23 pots with tomatoes as the crop, to compare the effect of bacterized peat with peat which contained no commercial bacteria. This was to parallel work conducted in the field with tomatoes and potatoes during the seasons of 1919 and 1920.

The tile experiment with apatite and barium sulfide, begun in 1919, was continued this season, with oats followed by buckwheat as the crop. This experiment comprises 46 tile.

A field experiment with bacterized peat, comprising two fields of eight plots each, was continued from the previous year. The purpose of this experiment was the comparison of a mixture of bacterized peat with one containing no commercial bacteria. The crops (tomatoes and potatoes) were rotated, the field which was used for potatoes in 1919 being used for tomatoes this season, and *vice versa.*

Feed and Dairy Section.

The Feeding Stuffs Law (*Acts and Resolves for 1912, Chapter 527*). — During the year 1,002 samples of feeding stuffs were collected and analyzed. The results of the year's work, together with a discussion of some feeding problems, have been published as Bulletin No. 13 of the Control Series. The official inspector visited 204 dealers located in 113 towns. One thousand four hundred and sixty brands of feeding stuffs were registered for sale in Massachusetts by 305 manufacturers.

On account of the greatly increased cost of carrying out the provisions of the feeding stuffs act with no increase in appropriation, local prosecutions have not been attempted, the Experiment Station continuing to depend upon the co-operation of the Federal authorities for action against violators of the law when the feeds entered into interstate commerce. On the whole, the market, while not entirely free from low-grade material, has been quite free from misrepresentation and fraud.

The Dairy Law (*Acts and Resolves for 1912, Chapter 218*). — The dairy law, so-called, requires operators of the Babcock test, where such test is used as a basis of payment for milk or cream, or for the purposes of inspection, to secure a certificate of proficiency from the Experiment Station. Fifty-one applicants were given the required examination and received certificates. The act requires, also, that all glassware used by licensed operators be tested for accuracy, and so marked. Six thousand and eighty-four pieces of glassware have been tested, of which only 13 pieces were condemned. In addition to the preceding, an annual inspection of machines and apparatus is also required. This inspection was carried out by Mr. J. T. Howard, authorized deputy, who visited 6 creameries, 33 milk depots and 46

milk inspection laboratories. Reinspections on account of repairs ordered will be necessary at nine places.

Miscellaneous Work. — Considerable time is used in making analyses of feedstuffs and dairy products sent in by citizens of the State, and of samples in connection with feeding experiments at the Experiment Station. Waters from wells or springs used as family supplies are also examined.

Considerable time has also been devoted to work not easily reported in terms of statistics, such as giving advice or information, either verbally or through correspondence, relative to feeding stuffs found in the Massachusetts markets, and to the formulating of rations. While such work is more properly an Extension function, an attempt is made to answer such questions where the answer is found in the chemical work with which we are directly concerned.

Testing of Pure-bred Cows for Advanced Registry. — The supervision of advanced registry is taking an increasing amount of time each year, and it is believed that it will be necessary very soon to make other arrangements in order to care for the work more adequately. Not less than nine and as many as sixteen men have been employed in making the two-day monthly tests. For the year ending Dec. 1, 1919, 4,150 two-day tests were reported; for the year just past 5,820 were reported, — an increase of 1,668 over the previous year. The number of cows on yearly test increased in one year from 416 to 519; the number of farms, from 58 to 72.

Summary of Two-day Test Work, December, 1919, through November, 1920.

Month.	Number of Supervisors, Whole or Part Time.	Number of Cows tested.						Number of Herds visited.					
		Guernsey.	Jersey.	Ayrshire.	Short-horn.	Holstein.	Totals.	Guernsey.	Jersey.	Ayrshire.	Short-horn.	Holstein.	Totals.
December,	10	166	130	85	4	31	416	31	11	10	2	4	58
January,	9	169	114	88	4	39	414	34	12	10	2	8	66
February,	16	178	138	79	8	52	455	35	11	10	3	9	68
March,	14	161	128	100	15	50	454	33	12	10	4	9	68
April,	11	161	130	107	19	72	489	32	10	11	4	10	67
May,	13	158	120	106	21	77	482	32	9	11	4	12	68
June,	10	167	118	103	21	89	498	29	10	11	4	12	66
July,	12	197	115	104	23	88	527	40	12	11	4	10	77
August,	12	175	113	107	24	91	510	30	11	11	4	11	67
September,	13	189	118	104	26	90	527	33	12	12	4	11	72
October,	11	198	120	103	28	80	529	34	12	12	4	9	71
November,	12	190	112	103	28	86	519	35	11	12	3	11	72
Totals,	–	2,109	1,456	1,189	221	845	5,820	–	–	–	–	–	820

The short-time tests for the Holstein Friesian Association did not fall off to the extent hoped for; in fact, about 46 more cows were reported than for the previous year. Statistics for the Holstein work follow: —

Number of farms visited,	32
Supervisors employed,	39
Reports turned in:	
120-day,	1
100-day,	1
60-day,	1
30-day,	58
14-day,	13
7-day,	261

Numerical Summary of Laboratory Work.

Samples sent to the Station.

Water,	60
Milk,	344
Cream,	378
Ice cream,	1
Breast milk,	2
Feedstuffs,	145
Fertilizers,	100
Lime products,	6
Soils for lime absorption capacity and organic matter tests,	137
Soils for complete or partial chemical analysis,	20
Arsenic determinations,	2
Vinegar,	7
Insecticides,	9
Cider for soluble copper,	9
Tobacco,	12
Control Work.	
Fertilizers,	1,311
Feedstuffs,	1,002
Samples Analyzed in Connection with Experiments.	
Milk,	168
Feedstuffs,	114
Fæces,	49
Urine,	14
Dry matter determinations on pot experiments,	288
Nitrogen determinations on pot experiments,	96
Phosphoric acid determinations on pot experiments,	44
Potash determinations on pot experiments,	48
Total,	4,366

REPORT OF THE CRANBERRY STATION.

H. J. FRANKLIN.

Investigational Work.

Insects. — The study of cranberry insect problems in general was continued. In co-operation with Mr. Walter Holmes, the gypsy-moth superintendent for southeastern Massachusetts, tests were made to determine the effectiveness of the open nozzle in spraying to control the gypsy moth on the bogs. General observations were also made concerning the occasional remarkable decrease in severe gypsy infestations during the development of the worms.

Hitherto unknown parasites of the cranberry girdler (*Crambus hortuellus*) were reared. A new control for this pest was developed, — namely, spraying with nicotine sulfate to kill the moths. In connection with this work it was observed that the insecticide was also destructive to leaf-hoppers and spring-tails which usually infest in great numbers the vines of bogs that are not reflowed, and probably reduce their vitality considerably. These tests and observations added materially to the mass of information from which must be developed the most practical program for spraying bogs which have water supplies for winter flowage only.

Tests were conducted to determine what strength of nicotine sulfate is most feasible for use in a spray to kill the moths of the black-head fire worm (*Rhopobota vacciniana*). Satisfactory results were obtained.

The brown span worm (*Epelis truncataria* var. *faxonii*) was unusually prevalent, the moths appearing in great numbers on even more bogs than in 1919. Many requests for advice on the control of this pest were answered, with the result that it did little harm except on a few neglected bogs. Important ob-

servations were made concerning the worm counts that precede serious injury by this insect.

The green span worm (*Cymatophora sulphurea*) was also unusually prevalent this season, and it completely destroyed what promised to be a very good crop on several acres in Duxbury. Important new facts about the life history of this species were learned.

By extensive examinations and counts it was found that the egg parasite (*Trichogramma minuta*) of the fruit worm was less prevalent than usual.

Important new observations concerning the habits of the root grub (*Amphicoma vulpina*) were made.

Five field meetings (in Rochester, Carver, Plymouth, Wareham and Sandwich) were held with cranberry growers to demonstrate the use of the insect-collecting net in discovering and determining the severity of certain insect infestations in their early stages. These meetings were planned as a special effort in the control of the gypsy moth, but the other open-feeding caterpillars often found damaging the bogs, such as span worms and army worms, were also discussed. A supply of insect nets had been prepared, and more than five dozen of them were sold to the growers for use on their bogs.

Weather Observations. — Weather observations were made as in previous years, in co-operation with the Weather Bureau, daily reports being telegraphed to the district forecaster in Boston.

A new method of making minimum temperature calculations for frost predicting, based on the Station records of 1913 to 1917, inclusive, was published in the "Monthly Weather Review" by the writer. Further records and studies were made during the season for the purpose of testing and improving this method. In forecasting for the local cranberry growers the method proved accurate enough to be very useful. Heretofore opinions concerning possible frosts have been given, with a few exceptions, to the local growers and those in the town of Carver only, the distribution of the warnings in Carver having been made possible by the generous co-operation of Mr. L. M. Rogers, manager of the Atwood Bog Company. This season, through the courtesy of the New England Telephone

and Telegraph Company, arrangements have been made to give out frost predictions in both the afternoon and evening to all the growers on the Cape who want them. This system of distribution was not completed until after the beginning of the fall frost period, but it should prove useful hereafter.

Disease Control. — Extensive further tests of arsenate of lead as a treatment of diseases causing cranberry decay were conducted, with results that strongly confirm those of former years.

Fertilizer Tests. — The fertilizer tests which had been conducted for about twelve years with generally negative results were discontinued.

Varieties. — The study of the characteristics of the cranberry varieties cultivated on the Cape was continued, special attention being given to seed counts. As a part of this work, small plantings of the Pride and Wales Henry varieties were made at the station bog.

Storage Tests. — At the end of the season storage tests were conducted to determine the effect of different containers on the rate of size shrinkage of the sound berries.

Blueberry Work. — Work with the blueberry plantation progressed satisfactorily, much more extensive budding of selected stock being done than heretofore. Satisfactory drainage of the plantation was provided by new construction. The quarter acre of cultivated plants yielded 147 quarts of fine berries, the largest of which were 20 millimeters in diameter. This seems a fair crop, as most of the plants were seedlings only five years old. The fruit was all sold locally at moderate prices.

For cranberry variety studies and the proper development of the blueberry work several acres more of rough land are needed, and an early appropriation should be made for its purchase.

Extension Work.

As usual, much time was spent in what should be classified as Extension work. This work was made more effective than heretofore through the presentation to the Station, by the Cape Cod Cranberry Growers' Association, of a Ford runabout.

This enabled the writer to visit bogs in distant towns more freely. This extension of the field of operation not only made the Station more serviceable to the growers, but also yielded some valuable results in the way of new observations.

Yield of Cranberries.

The Station bog yielded a crop of about 900 barrels, and this fruit sold at good prices, so the Station was more than self-supporting this year.

REPORT OF THE DEPARTMENT OF ENTOMOLOGY.

H. T. FERNALD AND A. I. BOURNE.

Report of Project Work.

The Onion Maggot. — Studies on control of the onion maggot have been seriously interfered with by the reduction of acreage of onions raised, owing to lack of labor in the Experiment Station. Only a small part of the acreage usually available could be obtained for experimental work on this subject, and the tests were less satisfactory for that reason. Such results as were secured, however, were distinctly favorable, and if an unrestricted opportunity to continue the work in 1921 can be arranged, and the year proves to be a "maggot year," it is probable that this project can be brought to an end.

Importance of the Codling Moth. — Studies on the importance and time of appearance of the codling moth have made satisfactory progress. Considerable information has been added to that already obtained, but the results thus far, it must be acknowledged, are rather perplexing. The usual directions as to treatment for this insect include spraying with arsenate of lead three to four weeks after the calyx spray. This time is rather too late for a fungicide spray, which should be applied about two weeks after the calyx spray. If the codling moth spray can be as successfully applied earlier, with the fungicide, a distinct saving will be made. The data thus far gathered are insufficient to settle this point, and the entire project evidently calls for further observations.

Studies on Common Scales. — Observations on the dates of appearance of the crawling young of our common scales have, as stated last year, shown that the original idea of the experiment could not be held to, but another basis for the work has

been found and promises to prove sound. If so, the data already accumulated will be of great value. Added to this as collateral items, observations on the dates of appearance of many of our other common insects and of the development of various plants in the spring promise much of interest along the same line.

Tests of Standard Insecticides. — Studies on the burning of foliage by insecticides are drawing toward an end. The results thus far are being tabulated and prepared for publication.

Studies on Digger Wasps. — These studies are progressing, though slowly. The project is a much larger one than was at first supposed, and with little time available for it, any marked advance in a single year is impossible.

The Squash-vine Borer. — This pest has caused a large amount of injury in Massachusetts the last few years, and a study of the insect and methods for controlling it have therefore been taken up this season. It is too early as yet to expect results, but several facts which may prove of value have already been obtained.

The Squash Bug. — This pest has also been studied to some extent the past summer. Work on it will be continued next year.

Studies of Spray Materials.

Studies of several materials used in spraying were made during the season, and the results follow: —

Aphicide. — There have been times when nicotine sulfate 40 per cent was not available on the market, owing either to an unusual demand or faulty distribution. At such times an effective substitute to use against aphids is desirable. Kerosene emulsion, employed for many years for these insects, is troublesome to make, and frequently fails to give good results. Anything which is an effective aphicide and also reasonable in price is, therefore, desirable to add to our list of insecticides.

Aphicide is a new material manufactured as a substitute for the nicotine sprays in controlling plant lice, and it was therefore tested during the season. Two samples were provided, one apparently more concentrated than the other. Both were clear liquids, the (presumably) weaker being almost colorless, the

other having a slight yellowish-brown tinge. Both mixed easily with water, and showed little tendency to separate out of the mixture on standing. The directions provided by the manufacturers for mixing called for $\frac{3}{4}$ to 1 per cent of the material and $\frac{1}{2}$ per cent of soap. The formula would therefore be: —

Aphicide,	$\frac{3}{4}$ to 1 part
Soap,	$\frac{1}{2}$ part
Water,	$98\frac{1}{2}$ to $98\frac{3}{4}$ parts

Such accuracy as this proved unnecessary, and various strengths of the material were tested, as the formula just given was too weak to kill the aphids. At 5 and 6 per cent, both grades of Aphicide proved very efficient, but were injurious to tender foliage. An increase of the amount of soap was then tried, and it was found that 1 per cent of soap with 4 per cent of Aphicide gave very satisfactory results without injuring the plants.

The conclusions reached as a result of these tests are that 4 parts of Aphicide and 1 part of soap in 95 parts of water make an effective material to use against aphids, and will not, at least under ordinary conditions, injure foliage.

Sulco V. B. — Tests of this material were undertaken at the request of one of the county agricultural agents who was much impressed by the comprehensive claims made by its manufacturers, these being that it is an insecticide, a fungicide and to some extent a repellent.

The material is a thick, heavy, oily substance readily miscible with water, from which it does not separate to any great extent until after standing for about twenty-four hours. It is claimed to be a mixture of a fish oil, sulfur and carbolic acid. The directions for application supplied by the manufacturers were to mix 1 part of the material with 25 parts of water for use against aphids, 1 to 30 for mites on evergreens, 1 to 100, with 2 pounds of arsenate of lead powder, against cucumber beetles, and 1 to 20 for ants in lawns.

Tests were made with this material for the control of ants, of plant lice, and of mites on evergreens, as a repellent for adult squash bugs, and to kill the eggs and young. Its effects on foliage, alone and with arsenate of lead, were also tested. In these tests the directions for preparation were fol-

lowed until the necessity for a change became evident. As a repellent against ants, it killed a few which were actually hit by the material; the others were not affected, nor was the prosperity of the colony as a whole checked perceptibly. Grass and other plants around the nests were killed. Against squash bugs it showed no repellent value and did not kill the eggs. It killed the young bugs, but when used strong enough to do this it killed the squash leaves also. Against mites on evergreens it proved fairly effective, but when any large percentage was killed, its strength had been necessarily increased to a point where it was not safe for the leaves. In the case of plant lice the strength recommended proved dangerous to the foliage of the plants, though killing the lice. Further tests, diluting the material at the rate of 1 to 60, and even 1 to 70, gave excellent results with the insects and no leaf injury.

Mixed with arsenate of lead the same results were obtained, and the conclusion was finally reached that Sulco V. B., at the strength recommended by its makers, is unsafe for use on most kinds of foliage; and that, when diluted to a point where it will not cause foliage injury, it is ineffective as an insecticide except for plant lice. For these pests, however, it can be diluted to a point where the leaves will not be injured and still kill the insects.

White Arsenic as an Insecticide in Bordeaux Mixture. — Some recent experiments, reported by Sanders and Kelsall (Proceedings of the Entomological Society of Nova Scotia, No. 5, for 1919), using arsenic instead of arsenate of lead or arsenate of lime in Bordeaux mixture, made it seem desirable to give a little attention to this subject. White or common arsenic costs less than the other arsenicals, "is the most concentrated form of arsenic, and consequently suffers least from freight rates, occupies less space, and entails the handling of less weight." If it can be used as safely and effectively as the other insecticides in combination with Bordeaux mixture, it should largely replace them, at least for some purposes.

Tests of this mixture on potatoes were made during the season, a very finely divided sample of arsenic being used. To prepare 50 gallons of the spray, half a pound each of white arsenic and fresh, unslaked lime were used. The lime was slaked in just enough water to keep the action brisk, and the

arsenic was slowly added during the slaking and thoroughly mixed in. After the slaking had been completed, water sufficient to make 5 gallons was added, and the whole thoroughly stirred. A sack containing 5 pounds of copper sulfate was then suspended in the mixture and shaken frequently until the copper sulfate had entirely dissolved. About a day later, when ready to spray, 5 pounds of lime were slaked in a few gallons of water, and diluted to make 25 gallons. The other mixture, prepared the day before, was also then diluted with water to make 25 gallons, and the two lots were poured together, stirred and sprayed.

It is evident that as a result of this work the material sprayed is no longer arsenic itself. It is probable that it, at least in part, combines with the copper, forming copper arsenite, which alone is often very injurious to foliage, but in this case is rendered non-injurious by the lime present. The Bordeaux mixture made in this way was green in color. Its suspension did not quite equal that of ordinary Bordeaux-arsenate of lead, but it adhered to the leaves fully as well. No leaf injury was observed in any case where this material was used, and good protection from potato insects was secured. No blight appeared on the potatoes.

The amounts of lead arsenate, both in dry form and as paste, required to furnish the same amount of poison (expressed in terms of metallic arsenic) as was supplied by one-half pound of white arsenic, together with the relative costs of the three materials, are as follows: —

Material.	Metallic Arsenic (Per Cent).	Material required to furnish Equal Amounts of Metallic Arsenic.	
		Pounds.	Cost.
White arsenic,	75	½	$0 11[1]
Dry lead arsenate,	21	2	84
Lead arsenate paste,	11	4	1 00

[1] In 50-pound lots.

Evidently the white arsenic is by far the cheaper material to use. There is a little extra labor in preparing the Bordeaux mixture with arsenic as compared with the use of the other

materials, but in practice this proved to be only a few minutes.

Where very finely divided arsenic can be obtained, therefore, its use in homemade Bordeaux mixture seems to be profitable, at least as a spray for potatoes.

Dry Sulfides as Substitutes for the Lime-sulfur Concentrate. — Dry sulfides have appeared on the market in recent years as substitutes for the liquid lime-sulfur. Reports as to their value have been conflicting, some claiming that they give good results, while others consider them worthless. The difficulties with the concentrate are several. Being a liquid it is more inconvenient and more costly to ship, and the material itself will not keep long if exposed to the air. It is also spoiled by freezing. These difficulties are all avoided by the use of dry materials, and if their effectiveness as insecticides is equal to that of the concentrate, the latter will surely be entirely discarded after a time.

This department has no opportunity to carry out field tests of these materials, but with the aid of the Chemical Department of the Station has made some studies on their composition.

The lime-sulfur concentrate contains calcium thiosulfate and calcium polysulfide. It is the general belief, sustained by experimental tests, that the polysulfide is the active agent of the mixture. The relative efficiency of these compounds is best measured in terms of their sulfur content. An investigation was made of the amount of polysulfide sulfur present in the lime-sulfur concentrate, in dry lime-sulfur, in barium tetrasulfide (B. T. S.), and in soluble sulfur (sodium polysulfide). In the comparisons which follow, spray made from the lime-sulfur concentrate, strength 1 to 8, was taken as the standard: —

Material.	Polysulfide Sulfur Present (Per Cent).	50 Gallons Spray made from Manufacturer's Directions.			50 Gallons Spray, Standard Strength.	
		Amount of Material used.	Cost.	Polysulfide Sulfur (Per Cent).	Amount of Material required.	Cost.
Lime-sulfur concentrate.	25.00	5⅝ gallons	$1 10	3.50	5⅝ gallons	$1 10
Dry lime-sulfur,	49.86	10 pounds	1 30	1.18	30 pounds	3 90
Barium tetrasulfide	43.19	11 pounds	1 54	1.12	34 pounds	4 80
Soluble sulfur,	47.97	12½ pounds	1 25	1.41	31 pounds	3 10

Evidently, then, the concentrate is the cheapest material by far. It is also evident that at the strengths advised by their makers, the other substances will have much less of the active agent present, and should be far less effective than the concentrate.

On the other hand, many who have used these materials report good results. Is this due to defective observations, prejudice in favor of materials so easily handled, or is it correct? If the latter, the question at once arises whether the concentrate is not stronger at 1 to 8 than is really necessary, and whether the other weaker materials are not, after all, strong enough for the work. To answer this, extensive field experiments under all kinds of conditions will be needed. It is possible that for years we have been using the concentrate stronger than is necessary, and that a greater dilution, bringing the percentage of polysulfide sulfur per barrel of spray down from 3.5 to about 1.25 per cent, would give equally good results. If this should prove to be true, the relative costs of the different materials would not be greatly affected, however, and the concentrate would in any case be the cheapest of the four by a considerable amount.

Extension Work.

There has been the usual demand upon this department for work of an Extension nature. Rather more than a quarter of the entire time of one man has been required to attend to duties of this kind. Correspondence, telephone and office calls, visits to places where assistance was needed, fumigation work, the preparation and demonstration of exhibits at fairs and during Farmers' Week, have made up this total.

The College Apiary.

The care of the College Apiary was under the supervision of Mr. J. L. Byard until about the middle of July. Unfortunately, Mr. Byard was taken ill at that time, and during the remainder of the year his work was necessarily carried on by the men in this department. Had this not been done, the colonies of bees would have been lost and the beekeeping

work would have come to an end, but the time required to prevent this loss to the College greatly reduced the amount of experimental work it was possible to do. Mr. Byard's death the last of November means the loss to the College of a faithful and industrious worker who had been for a number of years connected with the apiary here, and who had given liberally of his time and energy to the welfare of the work.

Insects of the Year.

While many kinds of insects were actively at work during the year, no outbreak such as that of the bean caterpillar in 1919 developed in the State in 1920.

As a matter of record it may be noted here that the gypsy moth made its appearance in Amherst in 1920 for the first time, but only in small numbers. Pelham and Belchertown are now also infested.

REPORT OF THE DEPARTMENT OF HORTICULTURAL MANUFACTURES.

W. W. CHENOWETH.

This department has but recently been organized, and because of crowded conditions in the laboratory, meager equipment and lack of efficient research assistants, the investigations carried on thus far are only preliminary to larger things to be taken up later. However, much valuable work has been done along the following lines: —

Jelly Making. — This is being studied from the standpoint of economic production. Results show that by proper handling of the fruit the yield may be increased two to three times the amount generally obtained by household methods; also that jelly of highest quality is produced where the amount of sugar is reduced to one-half or less than one-half the amount generally used. This fact has been of tremendous importance in recent years because of the sugar shortage.

The Economic Values of Varieties of Fruits for Manufacturing Purposes. — These investigations include both the small fruits and tree fruits. There is no doubt that varieties of fruit vary in their natural adaptability for canning and for the manufacturing of many fruit products.

Fruit Juices. — The manufacture and preservation of fruit juices for beverage purposes is an interesting and important problem. Many thousands of dollars worth of fruits are wasted annually in Massachusetts while our markets are supplied with fruit juices from the fruit plantations of the West. The work here also includes studies of improved methods in the home manufacture of vinegar.

Canning. — Study is being made of those factors that influ-

ence the processing period of canned foods, as well as studies of varieties of fruits best adapted to canning.

Cranberries. — The utilization of poor-grade cranberries is being studied this season.

When the necessary facilities are provided, the department plans to intensify and enlarge the above projects, and in addition to start further investigations looking to the solution of other perplexing problems connected with the preservation of fruits and vegetables.

REPORT OF THE DEPARTMENT OF HORTICULTURE.

J. K. SHAW.

There are at present four projects dealing with pomological questions under active investigation: —

The Interrelation of Stock and Scion in Apples. — The orchards devoted to this project have made satisfactory growth, and the usual records have been taken during the year. Some tabulations have been made which indicate that the stock materially modifies the growth of the tree, but these must accumulate for several more years before safe conclusions may be drawn.

The Genetic Composition of Peaches. — The orchard planted for this work has made fair growth, and several additional varieties desired have been secured. It will be a year or two yet before the trees come into bearing so as to permit extensive pollination work. A small quantity of pits of known parentage was planted in the spring of 1920, but for some unknown reason none of them grew.

A Study of Tree Characters of Fruit Varieties. — Last year some work was done on the study of variation and its relation to the theory of senility, and it is proposed to give some more time to this next year. Plans are made for a somewhat extensive study of leaf characters, which it is hoped may be completed during the season of 1921.

Pruning Young Apple Trees with Special Reference to Head Formation. — This orchard has made splendid growth, and is showing substantial results from the different methods of pruning. Unfortunately it was not pruned in the spring of 1920, and this omission will have an effect on the future be-

havior of the trees. The pruning in the spring of 1921 will, so far as possible, correct this omission.

Temperature Observation Work. — A large amount of data has accumulated from this work, and is now being tabulated and studied as to its relation to peach and apple growing.

Several new lines of work are under consideration in the hope that they may be undertaken in the near future. These center around the general question of soil management and fertilization of apples, peaches and bush fruits. Means of promoting the bud hardiness of peach should have some consideration, and we could well undertake some further work in pruning.

REPORT OF THE MARKET-GARDEN FIELD STATION.

H. F. TOMPSON.

Report on Project Work.

Manure Economy Test. — This was somewhat upset by the late spring, shortage of labor and insect injury, but the records show consistent progress.

Barium-Phosphate Test. — In the second season's test Barium-Phosphate has shown no particular benefit over acid phosphate as a carrier of phosphoric acid, and in several instances has seemed less efficient. Two tests were carried out, — one similar to that of 1919, the other with complete fertilizers, Barium-Phosphate being substituted for acid phosphate in one mixture. The crops under test were beets, carrots, cabbage, lettuce and spinach.

Martha Washington Asparagus. — The one-quarter acre plot of this asparagus has developed in a satisfactory manner. The first cutting was made the past season. Wide variation in size and yield is noticeable in different plants. Plans are under way for tests of individual plants to determine yields and characters, with a view to an elimination of the less productive units.

Limited Variety Tests. — These tests have proved of much interest, and point to some avenues of investigation which are projected for the future. The strain and variety test of tomatoes has been of much value, and indicates the possibility that ecological factors are of more importance for this crop than is commonly supposed.

Greenhouse Cucumbers. — In the greenhouses there has been a second test of cucumbers conducted in a similar manner to that of 1919. The cold, cloudy spring interfered with this

project, more particularly as it was necessary to depend upon heat from the sun, the heating plant not being completed. Ten strains of the greenhouse type of cucumbers, mostly from local growers, were under test, to determine the comparative yields. The first planting was made on the 3d of April, and picking did not begin until late in June. A bad attack of anthracnose greatly damaged the test. The total yield per plant averaged about one-half that of 1919. The variation in yield between strains, so far as this test indicated, was so slight as to leave the choice to market quality. In this there was considerable difference. As the Boston market calls for a long dark green type, the Belleville strain appeared superior, and the yields were approximately the same as for some of the shorter varieties.

Greenhouse Lettuce. — The project of improvement of lettuce for greenhouse production was started in the fall of 1920, with a test of some thirty-five strains and varieties of lettuce, collected from local growers and leading seedsmen in this country and abroad. By the 30th of November the test had not proceeded far enough to show results.

Increase in Equipment.

The equipment for experimental work has been increased by the completion of the heating plant and oil-burning apparatus, also the purchase of two additional recording thermometers. Each greenhouse is now equipped with self-registering thermometers, and a complete record of night and day temperatures is being filed.

REPORT OF THE DEPARTMENT OF METEOROLOGY.

J. E. OSTRANDER.

The work of this department has been continued along the lines of previous years without material change. The character of the work requires that after a definite form of records has been adopted it should be adhered to without much change if the records of different years are to be compared.

The regular semi-daily readings of the several meteorological instruments have been made and tabulated, and the self-recording instruments kept adjusted and running without any material stoppage. As some of the instruments have been in constant use for more than thirty years, frequent adjustments have been necessary. The time has come when a beginning should be made toward a renewal of the more important instruments. The more important records have been tabulated in the same form as when the station was started, so that comparisons from year to year may readily be made. The monthly bulletin of four pages has been prepared and published promptly at the close of each month.

The usual voluntary observer's reports have been sent to the Boston office of the United States Weather Bureau each month, and during the growing season weekly reports on crop conditions, precipitation, temperature and sunshine have been furnished the same office. Arrangements have been made to furnish the usual snow and ice reports to the Weather Bureau, as the snow and ice bulletin is to be issued again after having been temporarily discontinued during the war period.

Many requests for specific data regarding the weather on certain dates have been received and answered during the

year. The information asked for usually related to temperature at the time crops may have been injured in shipment, unusually heavy precipitation, wind direction or wind movement, or the general character of the day. This particular feature of the work of the department has greatly increased in the last few years.

REPORT OF THE DEPARTMENT OF MICROBIOLOGY.

C. E. MARSHALL.

The Experiment Station work in this department may be enumerated under three heads: —

Food. — The only workers in this field for the past year have been two graduate assistants giving half time, — Mr. Conrad H. Leiber and Miss Mary Garvey, the latter retiring from the work Oct. 1, 1920. Owing to this situation progress lags. Dr. Arao Itano, who gave some time to food study during the year, with the assistance of Miss Garvey, concluded a phase of this field of study, report on which will be withheld until another aspect of the subject is covered. The study in hand is a continuation of that of last year.

Dairy. — Although no recognition is given to the dairy studies by the Experiment Station, it may not be amiss to mention the fact that Mr. James Neill and Mr. R. C. Avery are engaged upon two very interesting themes out of which much is anticipated.

The past year two articles have been published in "Dairy Science," giving the results of the department's work on the De Laval studies: —

"Clarification of Milk," by Charles E. Marshall and E. G. Hood, together with Arthur N. Julian, S. G. Mutkekar and Max S. Marshall, in Vol. III, No. 4, July, 1920.

"An Association Study of *Streptococcus Lacticus* and *Bacillus Subtilis*," by Max S. Marshall, in Vol. III, No. 5, September, 1920.

Another article has been prepared by Max S. Marshall dealing with the possibilities of the clarifier, which furnishes a basis for its future development.

Soil. — Progress has been made in the study of microbial changes of organic matter of the soil. A step in the investigation of the problem, carbon dioxide determination (started in connection with Mr. L. C. Whitaker, who resigned July 1), has been developed and is now ready for publication. The study of the microbial decomposition of cellulose has been started in association with Mr. J. R. Sanborn.

Miscellaneous Work. — The analytical work of the department may be summed as follows: —

Bacterial counts on milk samples,	815
Water samples tested,	12
Medical specimens,	125

Legume cultures to the number of 299 were distributed.

REPORT OF THE DEPARTMENT OF POULTRY HUSBANDRY.

H. D. GOODALE.

The Elimination of Disease.

The chief item of interest in the work of the year is the drive made against disease, especially paralysis. The plan consisted in hatching from the old stock as usual, but taking the day-old chicks directly from the machines to a quarantined range where they were grown to maturity. At the close of the breeding season all old stock was sent to market, and the plant thoroughly cleaned and disinfected. In October the young stock was transferred to the renovated plant. The experiment was completely successful as far as the quarantined range was concerned, but a report on the remainder of the experiment cannot be made until more time has elapsed.

Project Work.

The fusion of the high-producing line and the non-broody line is complete. Broody birds still appear and doubtless will continue to appear for several years. Judging from this fall's performance, the egg production of this strain is likely to exceed that of any previous flock. Much more rapid progress could be made in the development of the high-producing strain if a thousand pullets could be trap-nested each year for the next two or three years.

A considerable amount of work of technical interest has been done on the reproductive organs.

Tillson Farm.

The assignment of the Tillson Farm to the Poultry Department will remove many hindrances to the progress of the experiments as soon as the transfer is completed and the farm is properly equipped.

DEPARTMENT OF VETERINARY SCIENCE.

JAMES B. PAIGE, D.V.S.

With the rapid multiplication of activities in the department during the past four or five years, the administrative work has increased to the point where it requires the attention of the head of the department for the greater part of the time for which he is responsible to the Experiment Station. The direction of the activities of the members of the staff, the preparation and development of the projects, conferences, keeping of accounts, etc., leave little time for the prosecution of investigational studies.

Diagnosis.

For many years it has been the practice in the department to invite the stockmen throughout the State to send in material from sick or dead animals for examination and diagnosis. This material comes from all species of farm animals. It frequently furnishes the best of specimens for study and use in the classrooms and laboratories. It also enables the department to keep in touch with the different diseases of farm animals throughout the State, and to locate the existence of an unusual disease in a particular locality. A report giving details of post-mortem findings, the cause of the trouble, nature of the disease and means of prevention and treatment is sent to the one sending in the material. By this means we feel that the department is rendering a valuable service to the stock owners of the State, along the line of disease eradication and control.

Correspondence.

From the preceding paragraph it is evident that a large amount of correspondence is necessary in connection with the diagnosis work. Each letter has to be of a personal nature, as hardly any two cases are exactly alike. In addition, many letters are received asking for information and advice relative to the treatment of diseases of the different species of farm animals. Conferences with stockmen from different localities frequently follow correspondence.

Control Work.

Nearly all of the more serious contagious and infectious diseases of farm animals are placed by law under the control of the Division of Animal Industry of the Department of Conservation. Among them may be noted bovine tuberculosis, glanders and mange of horses, hog cholera and others. There are some, however, belonging to the class, such as fowl cholera, fowl typhoid and bacillary white diarrhea, that do not engage the attention of the Division of Animal Industry.

Under an act of the Legislature passed in 1919 this department was given a small appropriation for the purpose of testing poultry for the elimination of disease. The entire amount appropriated, $3,000, has been expended in testing fowls for the diagnosis and control of bacillary white diarrhea. The act provides that a fee not to exceed 7 cents per bird may be charged for each bird tested. From Dec. 1, 1919, to Dec. 1, 1920, there were tested 19,982 birds, with receipts of $1,398.74. In addition to these receipts the department provided 12,810 leg bands for identification of birds from which blood samples were taken, for which the owners paid $64.05, making the total receipts $1,462.79. Deducting this amount from the amount of the appropriation, we have $1,537.21 as the total cost to the Commonwealth for this particular line of work.

Under the existing conditions of high cost of materials, travel, maintenance, etc., $3,000 was hardly sufficient to carry on the work to the satisfaction of all parties interested. In fact, it became necessary to suspend operations through the three

summer months. Under normal conditions there are but few demands for testing in summer. The hatching season is over and the poultrymen have not made up their matings for the next season. With a sufficiently large appropriation to carry on the work continuously throughout the year, however, the summer months could be used to very good advantage by the department in visiting the flocks tested earlier in the season and checking up the work, a procedure necessary in any effort directed toward the suppression and elimination of any animal disease.

It is to be hoped that the General Court at its next session will considerably increase the appropriation under the special act of May 23, 1919, thereby enabling us to carry on the work continuously throughout the year, to extend the field of operations to include a larger number of flocks, and thus to increase the services of the department for the benefit of the poultry keepers of the Commonwealth.

Investigations.

Bacillary White Diarrhea in Chicks; a Study concerning the Diagnosis of Bacterium Pullorum infection in the Domestic Fowl. — This project is being conducted as an Adams fund study, and the details are in charge of Dr. George Edward Gage. The laboratory studies of the problem have been completed, and a start has already been made in the preparation of the manuscript for a bulletin, which, it is expected, will be ready for the printer early the coming year.

Studies relative to Hog Cholera; its Complications, Prevention and Inherited Immunity. — These investigations are being carried on with a herd of from 75 to 100 hogs kept by a farmer here in Amherst and fed upon raw garbage that is collected about town, which, it is reasonable to infer, is liable at any time to be contaminated with pork scraps from localities where hog cholera exists. It is a well-recognized fact that many of the outbreaks of hog cholera occurring among Massachusetts hogs have their origin in fresh pork scraps that find their way into garbage. The work already done in connection with this experiment has shown beyond a doubt that hog cholera of the usual type can be prevented by the use of anti-hog cholera

serum and virus. There is also strong evidence that one application of the simultaneous treatment to weaned pigs possessing an inherited immunity is sufficient to protect the animal against the usual type of hog cholera throughout its life. The usual practice, at present, is to give weaned pigs a single dose of anti-hog cholera serum, and then, at the age of twelve to fourteen weeks, to give both serum and virus. If it is found that the simultaneous treatment at the weaning time is sufficient to protect throughout the life of the pig, the expense and trouble of two treatments may be avoided.

Special Problems.

Early in the year two special problems came to the department, each of which demanded immediate attention. A number of cows at the farm barn calved prematurely, and it was thought that contagious abortion had gained a foothold in the herd. At the poultry plant disease was ravaging the flock, as many as ten to fifteen birds being found dead on successive days. The condition became so acute that the farm committee of the Board of Trustees met to consider ways and means of dealing with the situation. As a result of their deliberations it was decided to procure the services of a graduate veterinarian to take the matter in hand, under the direction of the head of the Veterinary Department. Dr. John B. Lentz, a graduate of the Veterinary Department of the University of Pennsylvania, who had been a member of the staff of the Veterinary Department of the Experiment Station in charge of the poultry disease elimination work, and who, after his discharge from the service, had resigned his position, was secured to come to the department to take charge of these two special problems. He reported for service early in February, and at once began an investigation of each problem.

It was found at the farm barn that a considerable number of cows had given birth prematurely, but there was no conclusive evidence that the contagious form of abortion existed in the herd. A considerable number of cases of sterility, vaginitis, metritis and other complications of abortion existed in the herd. All of these conditions were taken in hand, and

the individual cows given appropriate treatment. Although the work is still in progress and cannot be completed until the time arrives for the next crop of calves, a marked improvement as regards the premature births and complications is to be noted at the present time. Cows that have not been bred successfully for many months are in calf, with every indication that they will carry the fœtus the full period of gestation.

Conditions at the poultry plant were far more serious than at the farm barn. A large number of birds showed symptoms of disease and unthriftiness. When the Veterinary Department was placed in charge of the poultry plant, early in February, it seemed probable that by appropriate methods of treatment of the entire flock of about 2,000 birds, it might be possible to eliminate the disease factor without resort to destruction of the entire flock. It soon developed, however, that we were able to make but little progress in arresting the spread of disease. After consultation with the representatives of the poultry staff, and acting largely upon their statement that the stock on the plant was not entirely satisfactory from the poultry husbandry point of view, it was decided to completely eliminate the old flock and clean and disinfect the premises, leaving them vacant for as long a time as possible before bringing a new flock onto the place.

To provide birds to take the place of those destroyed, eggs from the tested, healthy birds then on the plant were saved, incubated in sterile incubators, the chicks taken from the incubators in sterile baskets to a tract of land in North Amherst upon which no birds had been kept for years, and there raised under the direction of persons in no way in contact with the infected College plant. By this method about 2,700 healthy young birds were raised to take the place of the old, diseased flock that had been kept at the College plant.

As soon as all birds on the College plant had been disposed of early in July, a vigorous clean-up campaign was started. All houses and yards were cleaned, fences removed, yards plowed, etc. After the rough cleaning had been done, every building, with equipment, was thoroughly disinfected with a strong solution of a coal-tar disinfectant applied by means of a power spray pump, which made it possible to drive the solu-

tion into the smallest cracks and crevices. After plowing and harrowing, the yards were heavily limed, leveled and seeded. In those buildings where disinfectant solutions could not be used satisfactorily, sulfur fumes were used in combination with the liquid disinfectant to insure a perfect destruction of all infectious matter.

Early in October the clean-up work of the Veterinary Department having been completed, an inspection of the poultry plant was made by the farm committee of the Board of Trustees, who reported everything in a satisfactory condition. At this writing it is particularly gratifying to receive from Dr. Goodale, who is in immediate charge of the flock at the College poultry plant, the following: —

It is a pleasure to know that we have, thus far, no infectious diseases. Our mortality, aside from purely physical causes, has been practically nothing.

BULLETIN No. 195.

DEPARTMENT OF BOTANY.

TOBACCO INVESTIGATIONS.

PROGRESS REPORT, INCLUDING MISCELLANEOUS OBSERVATIONS ON TOBACCO.

BY G. H. CHAPMAN.

INTRODUCTION.

The production of cigar leaf tobacco has been for many years a very important agricultural industry in the Connecticut Valley, and in 1916 there were approximately 9,000 acres under cultivation in the Massachusetts section alone. By far the greater part of this was of the variety known as Havana, but some Broadleaf, shaded Cuban, and Sumatra were also grown. The value of the crop was estimated at, roughly, $3,600,000.

It can be seen from the above that the gross income derived from the growing of tobacco in Massachusetts is very large, and must of necessity be a very important factor in the regional community prosperity.

The successful raising, curing, and packing of tobacco is, as is well known, an art in itself, and very difficult of uniform attainment. The tobacco plant is very susceptible to comparatively slight changes of environment, and to grow tobacco successfully for a long period of years on the same soil requires, of necessity, extremely close observation and skill in agricultural practices. That success does not always attend the growers is more or less evidenced by the report alleging that the average yield in Massachusetts is falling off, and also that the percentage of wrapper leaves in crops is decreasing.

The season of 1915 was particularly unfavorable for the development of tobacco, and, as a consequence, the growers requested that experimental work be carried on by the station relative to ascertaining the fundamental underlying cause or causes of the apparent deterioration of the crop. No funds were available to carry on this work until the late summer of 1916, when an appropriation was made for this purpose. The collection of data relative to crop conditions and other phases of agricul-

tural practice was commenced at this time with a view to outlining experimental field and laboratory work for the ensuing years.

It has seemed unwise to make a yearly report until the data of at least two years were available, and therefore the present report includes the preliminary observations made during the latter part of 1916, and a discussion of the results obtained from the different lines of experiment suggested by these findings. These will be treated under their proper headings in the body of the report, with a general summary of conclusions and recommendations following.

Preliminary work was undertaken so late in the season that it was impossible to collect first-hand data on seed-bed conditions. The work was therefore confined to making a survey of the crop and soils in general, with a view to obtaining accurate information regarding the situation. After compiling and correlating these data it was planned to establish in 1917 experimental plots in different sections, and by various treatments endeavor to produce a favorable tobacco condition in the so-called "sick" soils. The problem is not primarily one of soil fertility, as it is generally true that crops other than tobacco — such as onions, corn, etc. — make a very luxuriant growth on the "sick" tobacco soils, and this often without additional fertilization.

Investigations necessary.

From the results of our study of 1916 conditions, it was apparent that the questions involved required the undertaking of several lines of investigation in order to reach a satisfactory solution. Undoubtedly it may be found necessary to change or modify the various experiments as time passes, but there are certain questions which should be answered as soon as possible. Among the more important are the following: —

1. Is the average yield of tobacco gradually falling off from year to year, generally, throughout the valley?

2. Is the quality of the tobacco produced inferior to what has been the average quality?

3. Has the weather factor been a primary controlling factor in production, — especially in later years, — and what limits are permissible for profitable production? (This hardly seems necessary of demonstration.)

4. Is there a correlation between weather factors and diseases, such as root-rots caused by *Thielavia basicola* and other organisms?

5. Aside from the general decrease in crops in 1915–16, and to a lesser extent in 1917, what is the cause of the soil "sickness" on some fields, or parts of fields? Is it due to a parasite, or is it due to improper fertilization and cultural methods?

6. Is there any correlation between the fertilization methods and soil treatment, and the activity of the root-destroying organisms? In other words, have we got some of our fields into a condition which favors the

development of the disease-producing organisms, and which, at the same time, is unfavorable for the optimum growth of the tobacco?

7. What corrective fertilization and cultural methods may best be employed in the latter instance?

Briefly, the investigation may be divided into three main parts, as follows: —

1. *A study of the meteorological factors as related to the growth of tobacco.*
2. *A biochemical study of the soils of normal and "sick" fields, including fertilization experiments.*
3. *A study of the micro-flora and micro-fauna of normal and "sick" soils, including those forms found to be parasitic on tobacco.*

Is the Tobacco Crop actually failing?

It has been repeatedly stated that the average yield per acre of tobacco in Massachusetts is decreasing gradually, and has been so doing for the past ten or fifteen years. This, if true, would be very alarming, and would indicate a widely distributed, serious situation due to parasites or to improper cultural methods. The following data will show the situation as it really is. Some years ago the United States Department of Agriculture, through its Bureau of Statistics, began reporting various data regarding the principal crops of the United States. Tobacco was included, and the following data have been secured from the annual figures as published in the various Year Books of the Department.

The average yield of tobacco in Massachusetts from 1870 to 1910 is calculated as 1,580 pounds per acre. At present this would seem a rather high figure, as the acreage devoted to shade-grown Cuban has increased in the past ten years, until in 1918 approximately 1,100 acres were devoted to this crop out of a total acreage of some 9,000. The yield of shade tobacco is much less than field-grown, not averaging over 1,000 pounds per acre, and this low yield of the Massachusetts acreage would of necessity, reduce the average yield, if yield is calculated on total acreage. However, as no other figures are available, the above-mentioned average is taken for the period 1870 to 1910.

The yield per acre is plotted in Fig. 1, and is self-explanatory. The straight broken line indicates the average yield. The heavy black line represents the seasonal variation.

It is at once apparent that until the disastrous seasons of 1915 and 1916 the yield over a period of fourteen years was, with four exceptions, well above the average, and two of these years, 1902 and 1913, were only slightly below the average. If we average the yields as plotted for the eighteen years we find that, even with the exceedingly low yield of 1915 included, the average yield for the period has been 20 pounds above the average yield calculated for the forty-year period of 1870–1910, — namely, 1,580 pounds.

It is only too true that the figures available are based on estimates which are, perhaps, somewhat at variance with the actual facts; but in

any case the factor of error would be identical from year to year, and the general comparative results may be considered trustworthy.

The yield has fallen off seriously only in 1915, and to a lesser extent in 1917; but in spite of these low yields the average yield of tobacco in the period 1900–18 has been above the average of the forty-year period 1870–1910.

There is no justification for the statement that the yield of tobacco on Massachusetts fields has been decreasing *gradually* for the past ten years; but, on the contrary, in spite of the exceedingly low yield of 1915

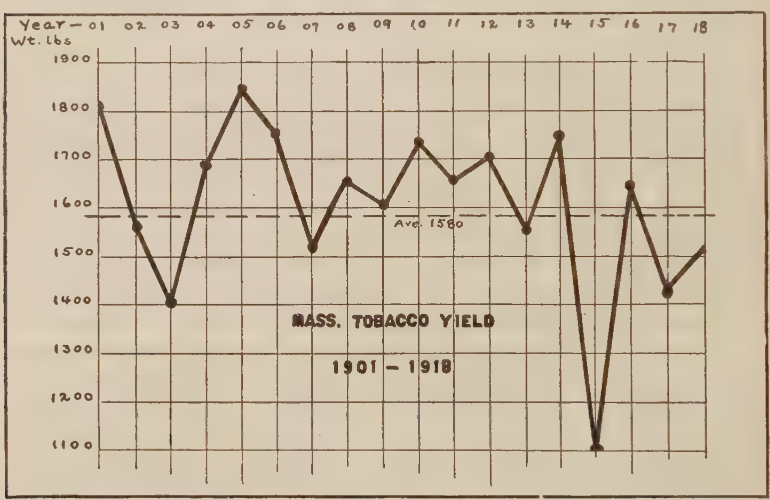


FIG. 1. — Average yield per acre of Massachusetts tobacco from 1901 to 1918, inclusive. The horizontal dash line indicates the average yield from 1870 to 1910.

the calculated average is being maintained. If, however, we consider only the yields of 1915, 1916, 1917, and 1918, it is true that a yield below the average will be found; but some of these seasons have been admittedly unfavorable for tobacco, from the meteorological standpoint, and high yields could not be expected. Also it is incorrect, or at least misleading, to base a statement of *general* yield on so few years' data. The same conditions meteorologically have in the past produced almost identical results, as will later be pointed out.

WEATHER FACTOR IN TOBACCO GROWING.

In general, it may be stated that the first half or more of the growing season of 1916 was decidedly unfavorable to the growth of tobacco. Conditions improved from shortly after mid-season until the crop was harvested, and a rapid and apparently satisfactory growth was made. The leaf was of good size and color, but although seemingly in good condition, was inclined — as later developments proved — to run rather light in

weight. There was a tendency on the part of many growers, resulting perhaps from their experiences in 1915, to harvest the crop before it was mature; whereas, as a matter of fact, the leaf matured in general rather late in 1916. This factor undoubtedly influenced somewhat the character and weight of the leaf.

It is a self-evident fact that rainfall, temperature, sunlight, humidity, etc., are very important factors in the normal growth of any crop, and perhaps exert a greater influence than usual in the case of tobacco, which is particularly sensitive to slight environmental changes. The season of

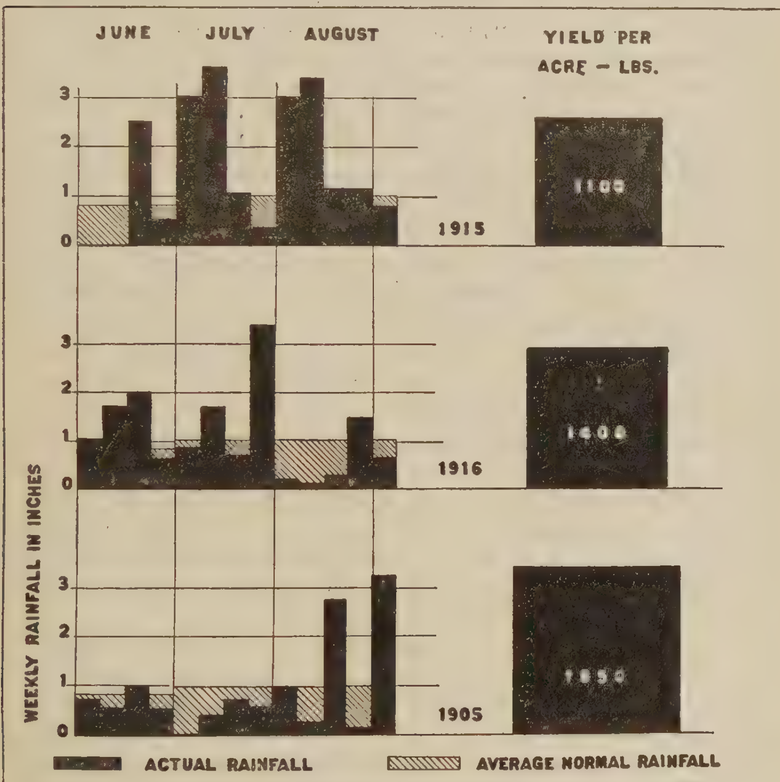


FIG. 2.—Comparison of actual rainfall and yield with normal rainfall for 1915, 1916, and 1905, a so-called "dry" year.

1915 was one of very heavy rainfall, as was that of 1916; therefore, as a means of comparison of conditions, the rainfall of 1916 has been plotted with that of 1915, and with a so-called "dry" year in which the crop was of good weight and quality. Fig. 2 shows the rainfall in inches week by week from June 1 to September 1, the variation from the normal, and the yield for each of the years. The correlation of excessive moisture and low yield is certainly very marked; also the converse: subnormal rainfall, well distributed, with a high yield.

It will be noted that the season of 1916, as a whole, was very wet, with excessive rainfall occurring during the first two-thirds of the growing period. The season of 1915, which was so disastrous, was even more wet; but a reversal of the 1916 conditions is found, most of the rainfall occurring during the last two-thirds or half of the season, when the crop was going through its period of greatest growth, and maturing. The season of 1905, while rather dry, produced many fine crops of tobacco (although they were later damaged by pole sweat), and it will be noted that the rainfall was low; in fact, the precipitation was below normal in many of the weeks and, as a whole, the season would be considered a droughty one. The fact that the last week or two were very wet, and consequently interfered somewhat with harvesting, does not in any way lessen the importance of the statement that the crop was very large. The quality, however, was slightly lowered.

There is no question but that the excessive precipitation of the two seasons first mentioned reduced the weight and quality of the crop; but its general effect was much less in 1916, when most of the excessive rains occurred in the first half of the growing season. These checked early growth in the field, but a subsequent return to normal, or thereabouts, in August allowed of a rapid development in the last few weeks, although, in spite of the favorable conditions, the crop was late in maturing. The excessive rainfalls of 1915 and 1916 have, in all probability, been an important factor also in intensifying the effects produced on the crop by the various forms of soil "sickness."

To illustrate: It was observed that on fields known to be badly infested with the root-rot fungus (*Thielavia basicola* Zopf.) the percentage of plants infected sufficiently to check growth was much greater than usual in 1915 and 1916. The apparent leaching out of certain plant foods, especially the more soluble forms of nitrogen, was also observable, as indicated by the character of growth on some fields. Mention will be made of a few interesting observations on this point later in the report.

The theoretical benefit which might be derived from the leaching out of the accumulation of soluble salines — which Haskins[1] found to be excessive (as compared with soils producing normal crops) in certain spots and fields producing unthrifty plants — was apparently observable in some cases and not in others. It is unfortunate that determinations of the change in amounts of these salines present in soils which had been previously examined were not made, but lack of time prevented this.

It is a well-recognized fact that rainfall, soil-moisture, and temperature all play an important rôle in the making of quality of tobacco, and it is also true that, as a rule, the finest quality of cigar leaf is raised on light soils which carry relatively only a small percentage of moisture, say from 7 to 15 per cent. Aside from quality alone, in seasons with excessive rains there is always a falling off in the crop, particularly as regards weight.

A study of the rainfall, relative humidity, hours of sunshine, and

[1] Haskins, H. D. Twenty-fourth annual report, Mass. Agr. Exp. Sta. (January, 1912), p. 35.

temperatures during the main growing season as compared with the weight of the crop has therefore been made. The data as to average yield and yearly production in Massachusetts were obtained from the various Year Books of the Department of Agriculture. These figures are the only ones available, and it is believed by the writer that in most instances, at least, they are reliable. The meteorological data are taken from the records of the Massachusetts Agricultural College observatory, and are fairly representative of conditions in this section of the valley. The observatory is located within two or three miles of the center of the Massachusetts tobacco area around Hatfield. Of course, observations taken only a few miles distant would differ somewhat, but only in minor details, and it is believed that we are fully justified in using these observatory records. No data are available as to seasonal differences in water content of the different soil types in the tobacco region in Massachusetts. The quality of the crop in the different years was also difficult to ascertain, as here it was necessary to depend largely on the grower's or packer's memory for data, and they often were unable to recollect a crop for a given year with sufficient accuracy to make a comparison reliable. Therefore quality has not been plotted.

The average yearly yield per acre in Massachusetts is given in Table I for the period from 1901 to 1918, inclusive, together with the average yield from 1870 to 1910.

TABLE I. — *Average Yield of Tobacco per Acre in Massachusetts, 1901–18.*

Year.	Yield (Pounds).	Year.	Yield (Pounds).
1901,	1,810	1911,	1,650
1902,	1,560	1912,	1,700
1903,	1,400	1913,	1,550
1904,	1,690	1914,	1,750
1905,	1,850	1915,	1,100
1906,	1,750	1916,	1,600[1]
1907,	1,525		1,400[2]
1908,	1,650	1917,	1,430
1909,	1,600	1918,	1,520
1910,	1,730	Average yield, 1870 to 1910,	1,580

[1] United States. [2] Massachusetts Agricultural College.

It will be seen that there is a marked variation in yield from year to year. The yield for 1916 as given by the United States Department of Agriculture (1,660 pounds) is much greater than the one estimated by the writer (1,400 pounds). This is probably due to the fact that the latter figures were obtained in part from the packing houses.

Fig. 1 is a graphic representation of the variation indicated by the above figures.

There was, unquestionably, a great reduction in yield in 1915, 1916, and 1917. *Can we look to a specific soil trouble, pathogen, or method of culture to account for this sudden and marked* GENERAL *decrease in yield?* It is hardly conceivable. A careful study of the yield in comparison with the meteorological conditions, however, does furnish us with important data, at least partially explanatory of the same. A study of Plates I and II (A and B), it is believed, will convince the most skeptical that the weather conditions during any given growing season determine to a great extent the yield, and that the *general* reduction in 1915 and 1916, as well as in other bad years, must be primarily attributed to these factors.

In these plates the normal for this locality is represented as the straight horizontal line or mean, and designated as (0). The variations of any given period — in this case, monthly — above or below normal are represented in black by the difference between the normal and that of any given month. Variations above normal are represented above the line, and below normal, below the line. Sunshine variation is given in hours, temperature variation in degrees Fahrenheit (F°), relative humidity in percentage, rainfall in inches, and yield in pounds per acre. Each season is divided into three parts, corresponding to the three principal months during which maximum growth occurs, — June, July, and August.

Studying these tables it is found that there is a rather close correlation between the various factors and the yield. Rainfall is, in Massachusetts, probably the most important factor bearing on the yield, followed closely by temperature and sunshine. The relative humidity apparently is not of such importance, so far as the actual yield is concerned. Calling attention to only a few of the more important differences will suffice.

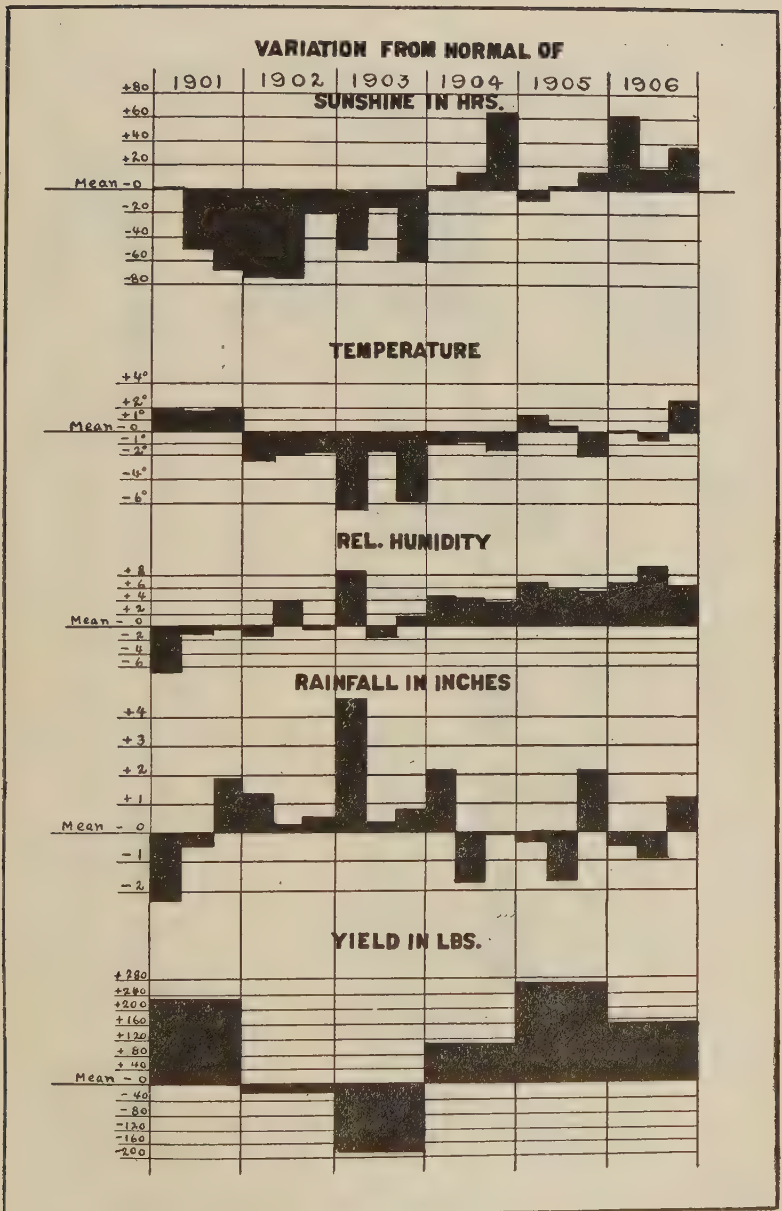
1915. — Sunshine slightly above normal in June, much below normal in July and August; temperature, 1.5–2.0° below normal for the entire growing season; relative humidity above normal except in June; rainfall practically normal in June, but from 4 to 5 inches in excess of normal during July and August; yield, 480 pounds below normal!

1916. — Here we have the reversal of conditions before mentioned: sunshine much below normal in June and July, above normal in August; temperature below normal for June, but above in July and August; rainfall excessive except in August, when it was 2 inches less than normal; yield better than in 1915, but still 180 pounds below normal.

1917. — Here we have a partial return to more normal conditions, but still somewhat abnormal; yield, 50+ pounds below normal for stalk tobacco.

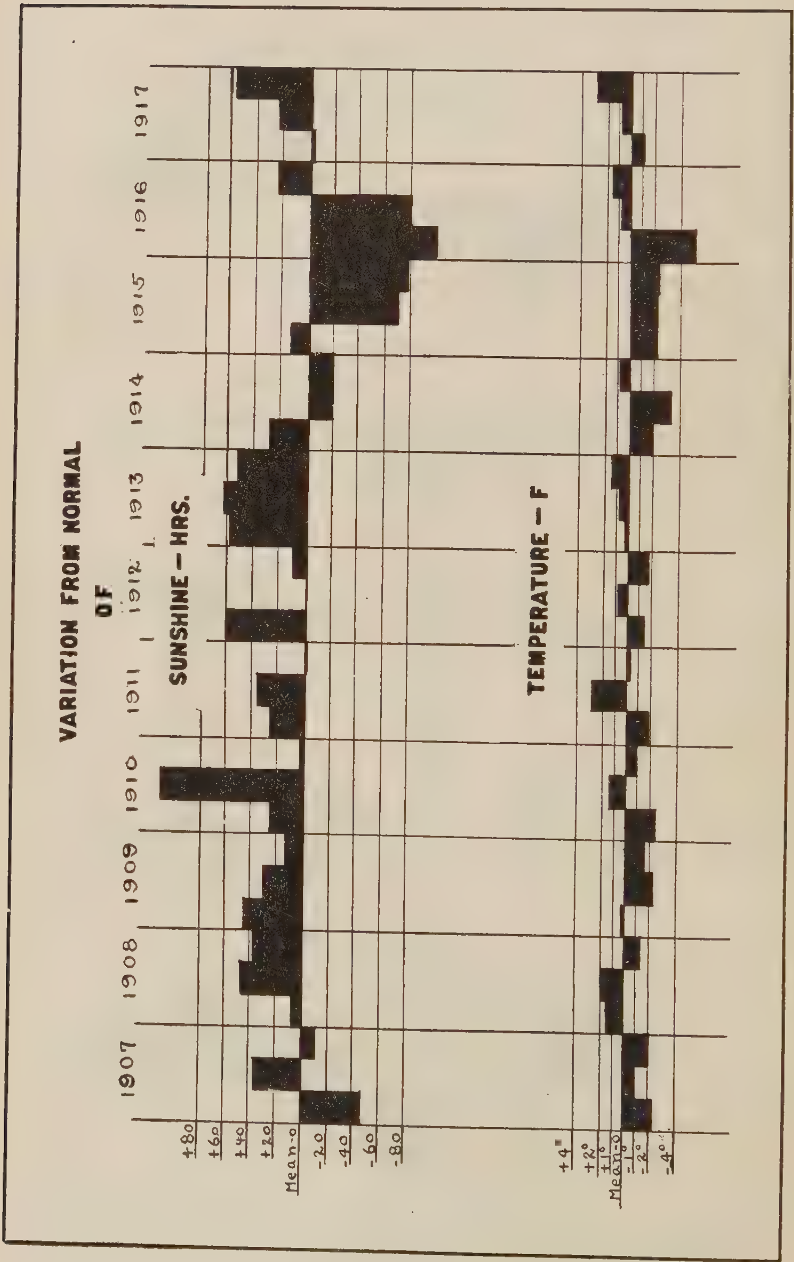
Going back still further it is possible to find analogous conditions in other years. It is safe to conclude that if there is excessive rainfall during the growing season, combined with low average temperature during the first half of the growing season particularly, the yield per acre will be small.

PLATE I.



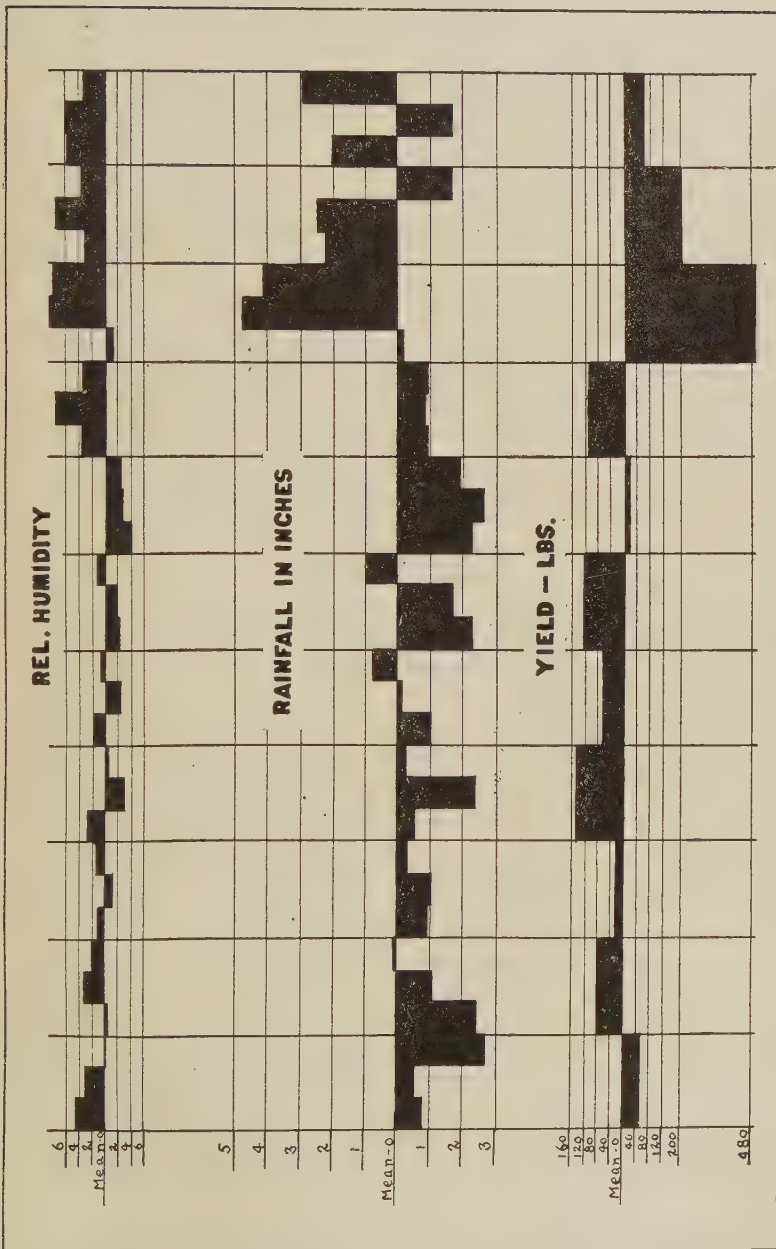
Variation from normal of sunshine, temperature, relative humidity, rainfall and yield, 1901-06, inclusive.

PLATE II A.



Variation from normal of sunshine and temperature, 1907–17, inclusive.

PLATE II B.



Variation from normal of relative humidity, rainfall and yield, 1907–17.

Excessive drought, combined with low or high temperatures, will also reduce the yield, but not usually to so great an extent as in the case of excessive rainfall. Good examples of the effects of drought on yield are to be found in 1907, and to a lesser extent in 1913.

Subnormal rainfall with subnormal temperatures does not reduce the yield to any great extent, providing they are not excessive (see 1909, 1910, 1912). The quality of the leaf is apt to suffer somewhat, however, in such cases.

A careful examination of the data leads us to the conclusion that for the development of our best crops we must have a season with normal or slightly subnormal rainfall, fairly well distributed, together with practically normal or supernormal temperatures.

Another factor of great importance is the distribution of the rainfall. For the best results the rainfall should be more or less evenly distributed over the growing period, not all in any one month or on a very few days of the month. The season of 1917 shows very well the effects of an unequal distribution of rainfall which, while averaging little above normal, reduced the yield. Here a very wet June, followed by a very dry July, brought the crop along to the danger point, and then the excessive rainfall of August, while helping growth, did not permit of a normal maturity, and as a result we get a subnormal yield.

As a result of the examination of these plates we may state that, in general, *rainfall is the major limiting factor of growth (and this necessarily includes soil moisture), together with temperature.*

Excessive seasonal rainfall is invariably followed by a reduction in yield independent of temperature.

Subnormal rainfall, when accompanied by temperatures excessively above normal, reduces the yield.

Subnormal rainfall, when accompanied by subnormal temperatures, does not apparently reduce the yield to any extent unless the rainfall is very much below normal.

In other words, there are apparently certain well-defined limits between which we may expect to get a normal yield, or better. A total rainfall for the season of from 6½ to 12 inches, if fairly well distributed, will give a good crop. Less than this or greater will give a yield below normal.

These conclusions are *general* and *seasonal*, and do not take into consideration other factors, such as *effect of precipitation* on soil temperature, fertilizer applied, parasitism of disease-producing organisms, type of soil, and method of culture. All these factors do play a more or less important rôle concurrently, but fundamentally rainfall and temperature are to be considered the limiting factors in production. The other factors mentioned are decidedly more local in their action, and are often possible of correction. They are what might be termed "individualistic," while the others are "communistic."

The effects, in any one season, of the rainfall and temperature as related to growth also make a very interesting study, and any one interested

would do well to read Bulletin No. 39 of the Bureau of Soils, United States Department of Agriculture, in which is reported a season's study of these factors at Tarriffville, Conn. It would be out of place to detail them here.

In conclusion, it might be well to emphasize again that the *general* reduction of crop yield per acre is invariably associated with the seasonal rainfall and temperature, and not to any "running out" of the land (which was amply shown by the fact that the 1918 crop, according to returns, was much improved over those of 1915 and 1916, and was practically normal in spite of the July drought), due, primarily, to a specific wide-spread soil trouble.

This conclusion does not in the least minimize the fact that in many localities there is undoubtedly trouble due to improper fertilization, methods of culture, and disease-producing organisms; but these are *specific* problems, and not susceptible to *general* analytical consideration except in the group to which they belong.

They *may* assume major importance in seasons presenting abnormal meteorological conditions, and in such seasons are often held responsible for all reductions in yield. This should not be done, however.

Soil Relations.

During the season of 1916 many fields were observed where the unfavorable condition of the crop could not be accounted for by the presence of disease. On these fields the leaf was apparently normal in size or, in some areas, small and undeveloped; but it was thin and papery, and did not show the weight and quality of normal leaf grown on the same type of soil. In these cases not attributable to parasitic organisms we must look to an unbalanced physiological relationship between the plant and the soil, and this, naturally, first involves a study of the soil composition, reaction, and methods of fertilization.

Many theories have been advanced to explain this particular type of non-productiveness of tobacco soils, such as overfertilization, under fertilization, excess of soluble salines, toxic substances formed in the soil by the interaction of certain fertilizing constituents, injurious fertilizer constituents, the accumulation in the soil of toxic excretions from the roots of the tobacco plant, lack of potash, and a variety of other causes any one or more of which may possibly, under certain conditions, furnish the correct explanation. In general, however, it has been found difficult to ascribe the condition of the crop on such fields to any one factor with any degree of certainty, and it would appear that careful investigation is necessary to clear up some of these questions. In all probability no single factor is responsible.

It has generally been supposed that tobacco thrives best on a soil approaching neutrality, but our observations lead us to believe that this may not be entirely true, and that, possibly, some of our soils are too

nearly neutral for the best development of tobacco. This seems to be particularly true where large quantities of lime have been applied to soils. The "good" tobacco soils examined showed a comparatively high "lime requirement," as determined by the Jones' method, using Haskins' factor for Massachusetts soils (4.46 instead of 1.8).

By the term "lime requirement," as used in this connection, is meant the amount of lime in the form of calcium oxide, CaO, it would be necessary to add to the soil to exactly neutralize it, *i.e.*, make it neither acid nor alkaline. It is not implied that the amounts of lime indicated in any given instance would benefit the tobacco crop.

The writer believes that, as a measure of the actual "lime requirement" or acidity of soils, none of the present methods of determination are satisfactory, and do not, in many cases, even approximate the true value sought; but when used as a comparative indicator for laboratory purposes in the examination of a series of soils they may be applied with advantage. In Table II will be found the "lime requirement" of some typical fields examined, together with comments on the crop, type of soil, etc.

TABLE II. — *Classification of Certain Soils according to "Lime Requirement," together with Data on Crop Condition, etc.*[1]

Group I.

Sample No.	Acidity indicated by CaO Requirement (Pounds).	Crop Condition.	Root-rot Infection.	Years in Tobacco.	Limed.
07	1,200	Very poor,	No,[2]	–	Yes.
03	2,700	Very poor,	No,	–	Heavily.
8	3,000	Poor,	Light,	–	Yes.

Group II.

Sample No.	Acidity indicated by CaO Requirement (Pounds).	Crop Condition.	Root-rot Infection.	Years in Tobacco.	Limed.
12	4,500	Poor,	Light,	–	Yes.
16	4,500	Poor; fair,	Light,	–	Heavily.
18	6,000	Fair,	Light; medium,	–	Heavily.
2	6,500	Very poor,	Very heavy,	6	Yes.
6	6,500	Thin; large growth,	Heavy,	40	Occasionally.
4	7,000	Poor; patchy,	Very heavy,	30–40	Occasionally.
14	8,000	Fair,	Light,	–	Little.
22	8,000	Very good,	Trace,	–	No.

[1] The data given in this table represent only a part of the total collected, but are typical of conditions in general.

[2] "No" indicates that no root-rot was found on roots of plants examined. It is entirely probable that a very extended examination might in all cases reveal a slight amount.

Table II. — *Classification of Certain Soils according to "Lime Requirements," together with Data on Crop Condition, etc.* — Concluded.

Group III.

Sample No.	Acidity indicated by CaO Requirement (Pounds).	Crop Condition.	Root-rot Infection.	Years in Tobacco.	Limed.
20	8,800	Good, . . .	No, . . .	–	No.
011	8,900	Excellent, . .	Trace, . . .	–	– –
A21	9,400	Very good, . .	No, . . .	4	No.
24	9,900	Good, . . .	No, . . .	–	– –
30	10,500	Good, . . .	Trace, . . .	–	No.
26	13,500	Very good, . .	No, . . .	2	No.
V17	15,500	A virgin soil ready for tobacco.			

The results are significant, and indicate that tobacco is making a better growth on soils which, with our method of acidity measurement, would be classed as rather acid. Until further investigation is made it would be unwise to emphasize this point unduly. Apropos of this, the general observations of Beals[1] on limed and unlimed areas substantiate, in a measure, these experimental findings. He found that out of 58 growers who made reports 43 had used lime more or less continuously, and most of these reported soil "sickness," while among those not using lime, only one case of soil "sickness" was reported.

A Study of the Reaction of Normal and "Sick" Soils as indicated by the "Lime Requirement."

In the past three years over 300 determinations of the so-called "lime requirement" of soils of all types used for tobacco have been made, as well as some of virgin soil broken for the first time for tobacco. The samples collected in different years were taken at approximately the same week or month, as the case might be, and as nearly as possible under similar conditions. In Table III there are arranged in groups the values obtained, together with brief notes on the condition of the crop during the season in which the samples were taken. It has not been attempted to include in this table, individually, all the soils examined, as this would be too cumbersome. The theoretical "lime requirement" is given in terms of CaO, and not as limestone or other commercial forms of lime.

[1] Beals, C. In report of thirty-third annual meeting of New England Tobacco Growers' Association. Feb. 16, 1916, p. 25.

Table III. — *Tobacco Soils arranged in Groups according to "Lime Requirement," with General Notes on Crop Condition.*

	Number of Soils examined falling in Group.	Condition of Crop.	Root Diseases Present.
Group I: — 0-3,000 pounds CaO requirement.	21	Poor; fair, . . .	None-slight.
Group II: — 3,000-8,000 pounds CaO requirement.	137	Poor; excellent (better as the higher limit is approached).	None-very heavy (usually present).
Group III: — 8,000-15,000 pounds CaO requirement.	29	Good; excellent, . .	None-slight (unusual).

The results given in this table apparently indicate that tobacco is making a better growth on soils which are rather more "acid" than we have been in the habit of believing to be best for tobacco. As a matter of fact, the soils which show the least acidity are those which have had in the past large and more or less consistent applications of lime, or those which have been planted to tobacco for a long period of time. Whether or not these soils which seem to be so "acid" actually are, is an open question. In all the methods of acidity determination used, we measure the amount of acidity and not the intensity, and it is being found that a determination of the concentration of the hydrogen ion gives us, often, different results.[1] These results are important, and bring before us the question of lime (for we reduce the acidity of our soils by liming or by certain systems of fertilization) and its use on tobacco soils. Do they indicate that we have been liming too much, and that if we keep off lime entirely for a time we will eradicate much of the trouble? This cannot be stated absolutely as a general proposition in the light of work carried on so far, but it can be positively stated that we have found many instances where lime, especially in active form, has been applied to soils with the result that in from two to three years the crop has been reduced considerably. This is particularly noticeable where lime has been dumped and then later spread. The areas on which the lime was dumped became very unproductive, and we are therefore justified in stating that it would be advisable to withhold lime from fields which have been in tobacco for some time, especially from lighter soils where the supply of organic matter is small. Apropos of the advisability of adding lime to tobacco soils, especially light soils, it should be noted that

[1] A study of the hydrogen ion concentration in our tobacco soils is in progress and nearing completion. This study is to include a comparison of results obtained by this method with those of the present report, and a discussion of the practical interpretation of the same. This paper, which will of necessity be more or less technical in character, will be published separately.

some of the fertilizers used are alkaline, and that most of the brands contain in the neighborhood of 200 pounds of some form of lime added for various purposes.

The question as to whether the addition of large quantities of lime is necessary on our soils for the best development of tobacco — and its effect on the burn, ash, etc. — is still open to investigation. It depends to a certain extent on the type of soil. Recent investigations by the Dutch East Indies station have shown that the addition of lime had little effect on these factors. On the contrary, in some cases where the burn was injured there was a beneficial effect on the quality and color. Other experiments showed opposite results, and in general no particularly good effects were observed.

There is no question but what some lime is necessary for the best development of the tobacco plant, but a small application every few years seems to be preferable to a heavy application two or three years in succession. The mechanical composition of the particular soil to which the lime is to be applied should also be carefully considered.

There is another factor, connected with the liming of our fields, aside from that of the direct injurious effect of lime on the growth of tobacco as a result of the changing of soil reaction toward neutrality. Certain of our experiments have shown that the fungus *Thielavia basicola*, which causes root-rot, is very susceptible to acids, and we have found that it is very difficult for the fungus to thrive on very acid media. On the other hand, on media approaching neutrality the fungus develops rather better and makes a far more rapid growth. We are at present testing out in the laboratory different concentrations of acids and different acids, together with soil extracts, to determine if there is any difference in their reaction on the fungus.

These data regarding Thielavia root-rot substantiate the findings of Briggs,[1] who in 1908 reported results on the intensity of root-rot infection on tobacco in alkaline and acid soils, and who also recommended the stopping of lime applications on infected fields.

Referring again to the preceding table it might be stated that the roots of plants on the various soils which were analyzed were examined for Thielavia root-rot infection, and some interesting data were secured. It was found that in the soils of Group I, as it has been called for the sake of convenience, — that is, those soils which showed a "lime requirement" of from 0 to 3,000 pounds CaO requirement, — the crop was very poor; but there was little or no Thielavia root-rot evident. On the soils which I have designated as Group II, the crop was poor and patchy, or good, and on many plants the Thielavia root-rot was present in sufficient amount to cause a marked loss of root-feeding area. These soils all fell within a range of CaO requirement of from 3,000 pounds to 8,000 pounds. In Group III were placed all the soils showing a "lime require-

[1] Briggs, W. The Field Treatment of Tobacco Root-rot. U. S. D. A., B. P. I., Circ. No. 7, 1908.

ment" above 8,000 pounds CaO, the crops of which were normal as far as growth was concerned, and many of them were very fine. In this group we find the acidity as measured in terms of the CaO requirement running as high as 13,500 pounds per acre. The highest value closely approaches the acidity of our virgin soils, such as are used when new tobacco plantations are established. Two of these virgin soils gave a "lime requirement" of over 15,000 pounds per acre.

From the preceding we can see that the situation with respect to liming is still further complicated. We have, on the one hand, the lime question and its effects on the growth of tobacco, pure and simple, and on the other, the effect of the soil reaction on the fungus which causes the Thielavia root-rot. If we lime continually and excessively land on which this root-rot is established, we are constantly getting it into a more nearly neutral condition, and hence into a more favorable condition for the development of the root-rot. In the end we will have a soil in which every year, irrespective of other factors favorable or unfavorable to the growth of the fungus, it will be able to develop vigorously and do great damage. In such cases soil reaction (changed by liming) should be looked upon as the primary cause of the trouble, and the presence of root-rot as secondary to this.

We find that this root-rot is not present to any great extent on soils showing a very low "lime requirement," which indicates that the soil is too alkaline for the development of the fungus, and also too alkaline for tobacco to make a satisfactory growth. At any rate, in this group (soils showing 0–3,000 pounds CaO requirement) the fungus is rarely found, though usually the crop of tobacco is very light and of poor quality. In the second group we find a large number of soils showing from 3,000–8,000 pounds CaO requirement, and it is to be observed that the Thielavia root-rot is present in a large number of fields. On these soils the crop varies from year to year, and in many cases is not of a satisfactory nature. On soils of this character in some years, however, good crops are produced, so we cannot here lay the damage to the lime alone, but must look to other additional factors.

In the third group we have soils which are acid and which show a high "lime requirement," — 8,000 pounds CaO and up, — but which are practically free from root-rot, and these soils are in practically all cases producing a good crop of tobacco. Does this not seem to indicate that the relationship between liming and Thielavia root-rot just discussed is a potent factor in many cases in the development of our troubles? There are, however, other factors to be taken into consideration, and in some cases these are of great importance also.

There is this fact patent, that on new land the tobacco always makes a good growth, although the quality of the leaf may not be all we desire. In these times, when the first consideration of the grower is apparently to get weight and let the quality come later, this is important, at least to the grower who has new land at his disposal. Most of the growers,

however, have not new land that is suitable for tobacco, and cannot extend their activities in this manner, so of necessity they must confine their attention to keeping their tobacco fields in good tobacco condition by careful methods of fertilization.

Mere weight should not be the aim of the grower, as eventually this will lower the standard of Massachusetts tobacco. It is a well-recognized fact that heavy, rank tobacco is not, year in and year out, in demand by the manufacturers, and the aim should be to produce a fair weight of tobacco which has quality. A satisfactory price must be obtained for such a product, and it is due to the low price paid, more than to any other single factor, that the growers are striving to increase the weight of the crop. The cost of production is so great in Massachusetts that to secure adequate returns we must continue to grow a wrapper crop of good quality.

To return to the question of soil reaction and the practice of liming, it might be well to emphasize again the data collected by Mr. Beals of this station in 1914 (*loc. cit.*).

It is true that some growers have been using lime more or less continuously for some time, and are still producing excellent crops of tobacco, but this is the exception, and other factors — such as soil composition, organic matter supplied, etc. — are more or less responsible for the success of these men.

Humus or Organic Matter Content of Massachusetts Tobacco Soils.

The soils reported in Table II were analyzed for humus content by the method of the Association of Official Agricultural Chemists [1] as modified by Rather,[2] and a somewhat wide divergence in humus content was found, as might be expected. There were found some indications of a relationship between humus content and crop condition, as well as "lime requirement." Low humus content was more often associated with low acidity and poor crop condition. It may be safely stated that many of the soils producing poor crops are deficient in humus. Usually the presence of an optimum amount of humus or organic matter in a soil is considered an essential to crop production, but whether the quality of the leaf is injured or not by large amounts of humus in the case of tobacco is of importance. Growth and weight, without quality, are not to be desired. The question of the addition of humus to soils, found markedly deficient in this substance, is one which will bear investigation. Where it is found necessary to supply humus, we have the choice of crop rotation or cover-cropping and manuring, and, as most growers feel that they cannot practice extensive rotation with profit, cover-cropping and manuring would appear to be the only satisfactory solution of the matter so far as the question of humus is concerned. Whether, as some firmly

[1] Official and Provisional Methods of Analysis. U. S. D. A., Bureau of Chemistry, Bulletin No. 107.

[2] Rather, J. B. Texas Bulletin No. 139. May, 1911, pp. 10–15.

believe, to restore the "sick" soils it will be necessary to rotate on a three or four year basis, is an open question, but one which should be seriously considered by those whose land is in very poor condition. It is to be hoped, however, that some treatment will be discovered which will render this unnecessary.

Continued examination of normal and "sick" soils during 1917 and 1918 has served to substantiate the findings of the first year. Almost invariably there has been found to be a relationship between the organic matter content of a given soil and the development of the crop. This was especially true in the case of old fields which had been heavily limed, and fertilized for years with "chemical" fertilizers. These same fields, as a rule, had had no addition of organic matter, except such as came from the cottonseed applied, or from the stalks plowed under.

Our light and heavy soils, of course, vary widely in the content of organic matter when in a virgin condition, and, as a rule, the light types are the first to be depleted of their organic matter. These also are the soils which contain normally the smallest amounts of organic matter. Continued liming depletes the organic matter very quickly, and in this practice we have undoubtedly exceeded the limits to which we may go and maintain a favorable amount of humus in the soil.

Some of the soils show a very low humus content, — even less than half of 1 per cent, — and in some cases, even on the heavier types of soils, we found less than 2 per cent. The natural organic matter or humus content of our tobacco soils varies from about $1\frac{1}{2}$ to 5 per cent or more, depending on the type of soil. It can be plainly seen that there is certainly a deficiency in many cases, and this should be remedied as soon as possible. Very few of the soils examined contained what would be considered the normal amount of humus for their type.

Organic matter is a very important factor in any soil, and particularly tobacco soils which are, in this section, cropped for years without any rest or rotation. Sufficient attention has not been paid to keeping up the supply of organic matter in the soils.

Organic matter affects the soil in many ways, both physically and chemically, and might almost be called a "soil regulator." Physically, it lightens heavier soils and binds lighter soils together and tends to make them loamy. It also increases the moisture-holding capacity enormously, and thus acts in a beneficial manner. Chemically, it adds to the plant food of the soil, as it contains the elements required by plants for food. Haskins' experiments at this station, in which he applied varying amounts of peat to some "sick" fields, showed very plainly that the peat exercised a beneficial effect on the growth of tobacco. These effects were due, probably, not only to the increase of organic matter in the soil, and the consequent action on the mechanical condition and water-holding capacity, etc., but also to the increase in soil acidity resulting from its application.

In our own experiments on "sick" soils — light and heavy — in the past two years we have shown conclusively that an application of even moderate

amounts of organic matter increases the weight of the crop to a marked extent. In these experiments the organic matter was applied in the form of peat in varying amounts, from 2 to 4 tons, on a 12 per cent moisture basis. The following tabulation will show the increase in yield resulting from the addition of organic matter, all other factors in the fertilization being the same.

TABLE IV. — *Increase in Yield resulting from Application of Peat to Certain Soils.*[1]

PLOT NO.	Peat Application (Tons per Acre).	Average Yield of Peat Plots (Pounds per Acre).	Average Yield of No-peat Plots (Pounds per Acre).	Per Cent. Increase.
A, F, K, ...	–	–	1,330	10
B, G, X, ...	2	1,470	–	
26, 23, ...	1	1,400	–	–2
1, 4, 6, ...	–	–	1,420	–
R, O, ...	2	1,570	–	10

[1] The plots received uniform fertilization aside from peat. Manure plots, and peat and acid phosphate plots, gave still higher yields.

While these data have been obtained for only two years as yet, it is believed that they are sufficiently striking to warrant tentative conclusions being made, particularly as the check plots which contained no additional organic matter were subjected to the same conditions as regards planting, cultivating, etc.

Except in certain rare cases the application of organic matter in the form of peat would be out of the question on account of the excessive cost of the material and the labor involved in carting and spreading. *How can we add organic matter to our soils at a cost sufficiently low to be practicable?*

There are several ways in which this may be done. There is added to soil a considerable amount of organic matter from stalks, cottonseed meal, manure, etc., but naturally this is not sufficient to replace the losses. Heavy manuring will apparently be sufficient sometimes, but this is an expensive form in which to apply organic matter. We cannot afford to practice any extended system of rotation, but we can supply an enormous amount of organic matter by "cover-cropping" or planting a crop in the fall after the tobacco is taken off, and plowing it under in the spring before planting.

COVER CROPS.

Cover-cropping should be practiced wherever possible, not only as a means of adding organic matter to the soil but also to prevent washing and blowing, in the case of light soils.

The choice of a cover crop depends on several factors, such as character of soil, presence of Thielavia root-rot in the field, etc. Some leguminous crop has often been advocated as a cover crop, but it is questionable if this is advisable for tobacco, as so many of the legumes (clovers, etc.) are also hosts of the Thielavia root-rot fungus, and would thus perpetuate it. *Any crop which will serve as a host for the root-rot fungus (Thielavia) should not be employed as a cover crop for tobacco.*

Rye, barley and timothy have been used in many instances with varying success, rye perhaps being most generally used up to the present time. There is one objection to rye, particularly on light lands; *i.e.*, if favorable growing weather prevails in the spring and any considerable amount of land is to be plowed, such a rapid growth of the rye top occurs that it is difficult to turn under thoroughly, and consequently it does not decay properly.

Barley is not generally used, and its use is not advocated.

Timothy has been used by some growers with good success, and from observation and trial on some soils the writer can recommend its use strongly, as it usually makes a good root growth, and does not grow so high as to be difficult of plowing under.

Although no positive data are at hand, it is believed that rye as usually planted will not furnish as much organic matter as timothy. Rye makes more top growth, but not nearly as much root growth as timothy.

According to our data, an ordinary cover crop of timothy will add to the soil over 2 tons of dry organic matter to the acre. Some figures of German investigators indicate even higher values, as much as 3 tons per acre.[1]

In addition to the direct benefit to the soil in organic matter, such a cover crop will aid in other ways. It will conserve nitrogen by preventing leaching, and will bind light soils, consequently preventing the blowing and washing which is so common in many fields.

The cost, per acre, for seed is very little, as the amount sown should usually be not over one-third bushel of good seed to the acre. The saving in nitrogen alone would more than repay the cost involved. The seed should be sown broadcast on stalk-cut fields, as soon as the tobacco is off, and on primed and shade-grown Cuban fields should be sown after the third picking at the latest.

Every tobacco field in Massachusetts should have a cover crop each year, and, so far as we can at present state, the choice should be timothy first, with rye second.

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[1] Subsequent to the preparation of this report the Connecticut station and Hartford County Farm Bureau published analyses showing that the average amount of dry organic matter returned to the soil by a timothy cover crop amounts to 3½ tons per acre. This would be, so far as organic matter content is concerned, the equivalent of 15 tons of manure.

Tobacco Diseases.

In the Seed Bed.

It may be stated on the authority of growers that while the weather conditions in 1916 were unfavorable to a rapid and uniform development of the seedlings, the beds were relatively free from parasitic diseases. Comparatively little damping-off of seedlings was reported, but the chief trouble seems to have been the checking of plants due to cool, moist weather conditions early in the season. After setting in the field, recovery was fairly rapid in most instances, and vigorous plants were produced. Judging from field examinations later in the season there probably was less "mosaic" in the seed beds than in some years past, as the number of mosaicked plants on a large number of fields observed was less than what is considered the normal infection.

The practice of sterilizing the seed beds by means of steam or formaldehyde — preferably the former for the sake of convenience — is on the increase, and with more attention being paid to such details as high pressure, complete sterilization of all soil in the beds, etc., more uniformly favorable results should be obtained.

It is believed, however, that the practice of sterilization of the same soil in seed beds year after year may not eventually produce the results desired, as we really know very little as yet about the action of steam on the soil, and its effects may prove detrimental if long continued. Thorough sterilization, when necessary, is recommended rather than indiscriminate, careless, or partial sterilization, which only adds to the expense of the crop.

As to the presence of the root-rot fungus (*Thielavia basicola* Zopf.) in the seed beds in 1916 no positive data are at hand, as our field work was started too late to allow of any examination of the plants in the seed beds. It is fallacious, in the case of root-rot, to draw conclusions from field observations as to its probable prevalence in the seed bed, owing to the fact that the causal fungus is apparently well established in many of our fields, and has been for some time. *It becomes generally of great importance, from an economic viewpoint, only in certain years when favorable environmental conditions for its development exist.* Thorough sterilization of the seed bed will also control this fungus when it occurs there. From data at hand it is believed that many seed beds, heretofore unsuspected, are infected to a certain degree with the root-rot fungus.

In the Field.

In order of importance and frequency of occurrence the diseases affecting tobacco in Massachusetts may be classified as follows: *Thielavia root-rot*, *"mosaic"* and allied diseases, *leaf spots* of various kinds, including *"rusts,"* *damping-off* in the seed bed, *stem-canker*, root-rots apparently induced by *Fusarium* or closely related forms, root-rots apparently induced by *Rhizoctonia* forms, *albinism* and similar chlorotic conditions, *sun-scald* of

leaves, *bud-scald*, and *hollow-stalk* caused by injury and secondary invasions of organisms causing decay, and killing of plants by fertilizer applications.

Some few of these occur rarely and are of little importance, as, for instance, *hollow-stalk*, which has been observed only occasionally. *Bud-scald* was prevalent in the spring of 1919 in some fields which were planted during the extremely hot dry period in the latter part of June. The injury was not noticeable until the plants had been in the field ten days or more. The midribs of the bud-clasping leaflets were the parts most seriously affected, and, as a result of the killing of some of the cells on the underside of the midribs of the leaves which were closed over the bud, these failed to develop naturally, and the normal development of the leaf web and the upper side of the midrib caused the pair of leaves affected to bend sharply downward and grow very irregularly. Never more than one pair of leaves was found affected on any one plant. This injury, while sometimes resembling the type of injury caused by bud-worm, is quite distinct from it. *Sun-scald* of the leaves is, of course, something which cannot as a rule be prevented, and is usually noted on the leaves which have been turned over by the wind, exposing the under side to the hot sun. If water droplets collect on the leaves when in this position, and they are then exposed to the hot sun, there develops on the exposed areas a peculiar type of leaf spot due to burning, the water drops acting as lenses. *Fertilizer-burning* was noted in a few cases, but was usually found only in seed beds which had been treated with a large amount of quick-acting nitrogen to hasten their growth. Elsewhere in this report are noted observations on the overapplication of ground fish to tobacco beds. *Albinism*, a condition in which parts of the leaf are almost pure white while the rest of the leaf is normal green in color, has been noted rarely, and its occurrence is of little import. This condition may arise from a variety of causes, and has even been observed as a result of early frosts, but usually the plants outgrow the trouble and develop green coloring matter in the white areas.

There has been found a root-rot which is more or less similar in its effects to that caused by Thielavia, with the exception that there are no pronounced black lesions on the roots, but a more uniform browning and dirty discoloration, most of the injury being found on the fine, feeding rootlets, and not on the larger ones, as is often the case in a Thielavia infection. A form of Rhizoctonia has been isolated from diseased roots, but as yet it has not been possible to make satisfactory reinoculations with the cultures obtained. It would appear, so far as our observations go, that the fungus may be weakly parasitic in nature. There is a "damping-off" trouble, due to Rhizoctonia, which is found in the seed bed, but in this case infection is usually found near the surface of the ground, and often when such diseased plants are set in the field there results, under favorable conditions, the disease of the stem known as "stem-canker." The root-rot apparently due to Rhizoctonia is usually found in restricted localities

in a field, and as yet is probably not of wide distribution. It remains to be proven whether the fungus is actually actively parasitic, or is capable of attacking only those plants which have become weakened by some other cause. As opportunity offers, work on this disease will be continued.

Root-rots, apparently induced by Fusaria or closely related forms of fungi, are seemingly on the increase, if we may take the isolation of these forms from diseased roots in almost pure culture as an indication of the causal agent. The roots of a large number of plants from patchy fields have been examined in the laboratory in the past two years, and in many cases forms of Fusarium, or closely related forms, have been isolated from the surface of the diseased roots. So far the few experiments in which it was attempted to infect the roots of healthy plants with pure culture material in the laboratory under control conditions have failed. It is a fact, however, that on many of the poorly developed plants in some fields we are consistently finding this fungus. A critical study of the question of Fusaria as the cause of a tobacco root-rot is being made by James Johnson of the Wisconsin station and the United States Department of Agriculture. In the writer's opinion, however, it may prove a difficult matter to establish the parasitism of this fungus, but it is to be hoped that something definite will result in the way of control measures. It should be noted that in fields where we have found the Fusarium associated with a root-rot of tobacco, there is a noticeable lack of infection due to Thielavia, the ordinary root-rot fungus of tobacco. This would indicate that the conditions necessary for the optimum parasitism of Fusarium are distinctly unfavorable to the development of the Thielavia. If this proves true, as these are both soil fungi, the question of control becomes rather perplexing. If it is shown that the Fusarium under certain conditions of soil reaction is actively parasitic, and these conditions are the ones that we have found to be practical for the control of Thielavia root-rot, the question of the finer adjustment of the soil reaction becomes an important factor, and more difficult of successful application.

Canker, noticeable in the field in 1916 as a decay and blackening of the stem at the ground, sometimes extending up the stem for some distance and occasionally girdling it, occurred only in isolated cases, and was of no importance economically. The direct causal organism, or organisms, is not well known, but the primary cause is probably due to a slight attack of damping-off in the seed bed, or even mechanical injury at the soil level, secondary organisms then gaining admission through the weakened tissue. So far the only field found to contain any considerable amount of canker is one to which very large amounts of manure were applied annually, the seed bed also being treated similarly. This excessive amount of organic matter furnishes a very favorable medium for the growth of bacteria and fungi, especially in the seed bed.

The leaf spots observed may be roughly divided into two classes, — those caused by organisms, and those with which no organism is associ-

ated. The second class is by far the more prevalent, and only in rare cases during 1916 were organisms found associated with a leaf spot. The amount of damage caused by leaf spots of this character is apparently slight, judging from the data at hand, but it is possible that more extended examination of fields may show different results.

The leaf spots not due to organisms were rather numerous in 1916, especially those classed as "rusts" by growers. One type of these "rusts" is usually found associated with the mosaic disease, and here the rusted spots which are made up of dead tissue are rather large and often coalescent, so that a comparatively large leaf area may be affected. Another type of "rust," believed by the writer to be associated also with the later stages of mosaic, was observed. In this case the spots were small, more regular in outline, not coalescent, and more thickly distributed over the leaf. There is some question, however, whether this type is always associated with the mosaic disease, as the same condition has been observed occasionally on plants not affected with this disease. In some shade-grown areas another type of spot or "rust" was observed, and it was not associated with mosaic. Here the spots were small, regular in outline, and widely scattered, some of the leaves showing only one or two such spots. It is not certainly known what the cause of this type of spot is, but it resembles a spot found in other tobacco sections where a lack of potash is said to exist. It may be due to other causes, however, and it is useless to even hazard an opinion on the question at this time. The whole matter of leaf spots requires investigation, particularly those spots which are not caused by organisms. It is expected that a study of these troubles will be taken up at a later date.

Mosaic disease was present in 1916 on many fields, but from an estimate of the amount on fifty-one areas it was apparently not present to so large an extent as in some years, approximately less than 3 per cent of the plants having the disease on commercial leaves. No account was taken of plants contracting the disease on the sucker growth appearing after topping, as it is believed that the presence of the disease on such growths does not affect the commercial leaves. The percentage of infection, in general, that season (1916) was below what may be considered the normal infection. (This count, however, included three very badly infected fields where a large percentage of the crop was affected, and this raised the percentage of infection considerably.) The prevalence of mosaic disease seems to be less than it was some years ago, and there has been only relatively small damage from this trouble in the tobacco section, as a whole, in the past two or three years. If more attention is paid to careful handling of plants in removal from the seed bed and during transplanting, the damage resulting from this disease can be reduced to an almost negligible amount. More attention should also be paid to fitting the land and keeping it in the best condition during the transplanting time and until the plant has obtained a good start. There is no question but that proper attention to such details and to the rejection of diseased plants in the seed

bed will go far towards controlling the trouble, but it is improbable, owing to its nature, that it will ever be entirely eradicated. A good indication as to whether an infection is from the seed bed may be obtained by making a note of the time, after planting, of the first appearance of the disease in the field. If the disease is noticed at any time within a period of two weeks after setting, one may be sure that the infection came either from the seed bed or during the transplanting. If it appears after this length of time it is usually the resultant of a field infection. If all the leaves show the trouble it may also be stated that the infection came from the seed bed or from the conditions under which the plants were set. If it appears on some of the upper leaves at a later period the infection occurred in the field, and soil conditions should be looked into. A full discussion of the mosaic disease will be found in Bulletin No. 175 [1] of this station, a copy of which will be mailed on request to the director's office.

Thielavia root-rot, or the ordinary root-rot of tobacco, is probably the most widespread trouble of fungous origin we have in our tobacco fields, and as a primary and secondary cause of many of our "sick" fields it is of great importance.

This disease appeared to be more destructive in 1916 than usual, although the amount could not be compared with that of 1915, as no extended examinations were made during that season. Many fields presenting an unthrifty appearance were studied with the idea of obtaining data as to the presence of root-rot, but in some cases only slight infections were found, the root systems of the plants not being parasitized sufficiently to account, in our opinion, for the general unthrifty appearance of the field. However, some cases were observed where the plants on entire fields were, to a large extent, badly infested with the root-rot fungus, and unquestionably these fields are in need of immediate treatment looking toward the eradication of this trouble. In nearly every case these heavy infections were on fields long used for growing tobacco, and the soil reaction and other factors were rather abnormal. It would appear from the observations made during the season of 1916 that in our fields the causal organism of Thielavia root-rot is widely distributed, but produces noticeable ill effects only when the soil and its environment are unfavorable to the best development of the tobacco plant and favorable to the rapid development of the root-rot fungus.

The control of this disease in the seed bed has already been discussed. There is no question but that it can be completely controlled by thorough sterilization either by steam or formaldehyde. The control of the disease in the field is an entirely different matter, however, and it is practically out of the question to attempt to eradicate it in the field by methods used for its eradication in the seed bed, because of their prohibitive cost. Even if the cost of material were considerably less than it is at present the labor and time factor would render such methods prohibitive. It is believed by some that a method of control by steam or formaldehyde can be devised, and that it will not be impossible of application from the

[1] Chapman, G. H. Mosaic Disease of Tobacco. Mass. Agr. Exp. Sta. Bull. No. 175 (1917)

economic point of view; but so far this has not been done. It may be possible to apply some compound in a dry state to the field, and to do it economically, but any application of a salt in solution would demand so much water to obtain the requisite penetration that it would be out of the question. So far a dry compound possessing the requisite fungicidal action has not been discovered. Certain solutions and salts have been used experimentally, but unfortunately none can be recommended for use on a commercial scale. A brief statement of the results obtained in our experiments with various compounds will be given below. It is believed that control can be better obtained by changing the soil reaction to a more acid condition by means of fertilization and cover-cropping, as has been indicated. The whole question of the prevalence of root-rot and its infection in our fields is closely bound up with the question of soil reaction, and it can hardly be profitably discussed apart from that problem. We have been able, by the use of cover crops and acid fertilizer materials, to "bring back" some heavily infested fields in a remarkably short time, and have no hesitation in recommending the use of a timothy cover crop and the non-application of lime to fields infected with the Thielavia root-rot. Of course there may be danger of getting our soils into a condition too acid for the best growth of tobacco, and judgment should be used in the application of any raw acid materials. The grower should not forget that "while a little may be a good thing, too much may be highly injurious." An increase in the amount of phosphoric acid, applied in the form of acid phosphate, has been found to have a beneficial effect, and apparently does not adversely effect the quality of the tobacco. In our experiments application of both "aged" and "raw" acid phosphate, in amounts of 400 and 600 pounds additional to the acre, has given uniformly good results, particularly on the lighter soils.

Thielavia Root-rot Investigations.

A statement of the results of some of our experiments having to do directly or indirectly with the Thielavia root-rot has been made in connection with other lines of work. Some of the experimental work, while interesting and fundamental from the scientific standpoint, can hardly be made use of at present as a basis for the treatment of infested fields. As a matter of record, however, a brief discussion of experiments is included in this report. The first work undertaken was the attempt to control the disease in the field by the application of chemicals to the soil. The data presented represent the work of two years. The plots were located on fields known to be heavily infested with Thielavia root-rot. The substances used were formaldehyde, copper sulfate, iron sulfate, mercuric chloride, potassium permanganate, sulfuric acid, sulfur, and "By-product A," a commercial preparation. With the exception of the sulfur and "By-product A" the substances were all applied in solution. All plots were in duplicate. The following table will indicate the amounts applied, calculated to an acre basis. A check plot (no treatment) was left between every two plots.

TABLE V. — *Chemicals applied, and Rates of Application.*

	Pounds per Acre.		
Formaldehyde,	4,800	2,400	1,200
Copper sulfate,	400	200	100
Iron sulfate,	1,000	500	50
Mercuric chloride,	100	75	25
Potassium permanganate,	300	100	50
Sulfuric acid,	1,200	600	300
Sulfur,	2,000	1,500	1,000
"By-product A,"	4,000	2,000	1,000

The sulfur and "By-product A" were applied dry and thoroughly mixed with the 3 inches of top soil. The formaldehyde was so diluted that it was applied at the rate of one-half gallon of solution to the square foot of surface. On the first year's plots observations of a miscellaneous character were taken in addition to the root-rot data. The observations relating to growth are noted in the following table. They were made two weeks before harvesting. The growth data are calculated on the basis of the checks equalling 100, the plots being greater or less than this.

TABLE VI. — *Table showing Development of Tobacco in 1917 on Chemically Treated Plots.*

Chemical.	Amount applied (Pounds per Acre).	Color.	Growth (Check = 100; no Treatment).
Formaldehyde,	4,800 2,400 1,200	Normal, Normal, Normal,	100 125 125
Sufuric acid,	1,200 600 300	Normal, Normal, Normal,	125 100 100
Sulfur,	2,000 1,500 1,000	Light, Normal, Normal,	40 60 100
Mercuric chloride,	100 80 25	Normal, Very dark, Very dark,	45 90 100
Copper sulfate,	400 200 100	Normal, Normal, Normal,	100+ 110 110
Ferrous sulfate,	1,000 500 250	Light, Normal, Normal,	94 87 100
Potassium permanganate,	300 100 50	Normal, Normal, Normal,	87 85 85
"By-product A,"	4,000 2,000 1,000	Normal, Normal, Normal,	94 94 100

It will be noted that the only substances which did not have an inhibiting action on the growth were formaldehyde, sulfuric acid, and copper sulfate. The rest of the chemicals applied did inhibit the growth of the tobacco, at least in the amounts applied.

A careful examination of the root systems of the plants in the different plots was made by Mr. Krout of this department, who was in direct charge of the root-rot work, and he reported as follows: —

TABLE VII. — *Comparison of Treatment with Thielavia Infection and Root Development.*

CHEMICAL.	Application (Pounds per Acre).	Thielavia Infection (Check Infection=100).	Root Development (Check=100).
Formaldehyde,	4,800	0+	100
	2,400	15	150
	1,200	15	125
Sulfuric acid,	1,200	88	75
	600	95	103
	300	88	125
Sulfur,	2,000	80	38
	1,500	70	65
	1,000	80	90
Mercuric chloride,	100	83	78
	80	83	88
	25	88	90
Copper sulfate,	400	75	123
	200	85	108
	100	90	108
Ferrous sulfate,	1,000	90	70
	500	90	95
	250	100	115
Potassium permanganate,	300	90	100
	100	60	100
	50	95	100
"By-product A,"	4,000	100	93
	2,000	88	105
	1,000	90	95

From the above it may be seen that the only substance used which checked the development of the root-rot, or controlled it to any great extent, was the formaldehyde. The root growth also was apparently stimulated by the lower concentrations. Sulfur, mercuric chloride, and ferrous sulfate, while reducing the root-rot to some extent, had an injurious effect on root development. The copper sulfate and sulfuric acid reduced the amount of root-rot infection somewhat, and did not apparently, except in the case of the greatest strength of sulfuric acid, reduce the root development to any extent.

These experiments were continued in the following year with comparable results. It would seem that none of the substances used, with the exception of formaldehyde, were sufficiently beneficial in their action to warrant

further experimental work at this time. The cost of this material and the labor involved, together with the large amount of water which is necessary, render it inadvisable to recommend this treatment on large areas. Small areas in a field might be so treated.

The sulfuric acid treatment did not give the results anticipated, but possibly a variation in amount applied might give more beneficial results. In this case, however, we should have to take into consideration the possible residual effect of the SO_4 radical (sulfate). Further data on this point will be available later. It would seem that, in view of the fact that Thielavia is so susceptible to acids, this might be a method of at least partial control.

The benefits to be derived from increasing the organic matter and general condition of the soil, in relation to the Thielavia root-rot, have already been briefly discussed, and further mention of them will be omitted.

Much laboratory work is in progress with the Thielavia fungus to determine the specific action of the different acids and bases on the growth and development of the fungus in culture, as well as to determine the limits between which the fungus is actively parasitic. The results, however, will not be discussed in this report, as additional work is necessary on this phase of the problem.

Fertilizer Experiments in Progress.

Beginning in 1917 there were established three experimental field plots on different soil types in the tobacco section. The yields on these fields were very low, so low on one of them that the crop had not been harvested. On one of the fields there was abundant evidence of a very serious Thielavia root-rot infection; on the other two, however, although the root-rot was present it did not appear to be of primary importance.

The experiments were designed to be general in character, and dealt with three principal questions, namely: (1) Are our soils in need of organic matter, and if so what is the response of the crop to the direct addition of the same in the form of peat, or in the form of stable manure? (2) Are our soils lacking in potash, owing to the inability of the growers to procure the usual amounts of the same since 1914, and if there is a lack how is it evidenced? (3) What benefits, if any, are to be derived from the addition of increased amounts of phosphoric acid in the form of acid phosphate to the normal fertilization? This question was suggested by the fact that very good results have been obtained in many cases by rotating tobacco and onions, and the latter crop is usually treated with a fertilizer containing a large amount of acid phosphate.

The results of 1919 are not at present ready for publication, but some rather definite results were obtained in 1917 and 1918. These will be briefly discussed here. The details of the experiments will not be taken up in this report, as the work is of sufficient volume to require a separate report, which is to be issued as soon as possible after the 1919 crop has

been gone over and the results tabulated. Two of the plots were Havana and the third Cuban shade-grown. There has been a general similarity shown by the results on all of the plots.

In addition to the special treatments indicated below, it should be remembered that all the plots received an application of a 5–4–5 mixture, equivalent to an application of 3,000 pounds of commercial mixed goods of the same analysis per acre, except, of course, the no-potash plots. These received no potash in any form, except such as was in the manure or the cottonseed.

There was a marked increase in yield both in 1917 and 1918 on the plots which had received an application of organic matter in the form of peat at the rate of 2 tons to the acre (on a 12 per cent moisture basis), and also a slightly heavier yield with better quality on the manure plots than on the peat, the manure being applied at the rate of 10 tons to the acre. There was a still more marked increase in yield on the plots which had received organic matter, either as peat or manure, and acid phosphate at the rate of 300 to 600 pounds per acre. Where acid phosphate alone was used in conjunction with the regular fertilization without the addition of organic matter in some form the results even on the same plot were sometimes rather conflicting. It can only be stated that no uniformity of results was obtained. In some cases a marked benefit was noted as a result of the treatment; in others, on the same field, the results were apparently negative.

With respect to the lack of potash it was noticeable that there was no lack of this material indicated on any of the plots in 1917 and 1918. No differences were observed, so far as this material was concerned, between the plots which received applications of 350 pounds of high-grade sulfate of potash and those which received none at all. It should be stated, however, that the experimental plots were all located on land which had in the years prior to 1914 received liberal applications of potash, and it is quite probable that the supply of available potash in the soil was in no case exhausted. During the growing season of 1919 there were indications that on one of the fields there might be developing a lack of potash. The symptoms were not characteristic enough to warrant a positive statement on this point.

There is no evidence that our soils in general are suffering from a lack of potash, although a few local areas where this was the case have been brought to our attention during the past year. These cases were all on light soils and on soils which had not in the past received any heavy applications of potash in the fertilizer used. It would appear that new soils which have been used for a comparatively short period only before the shortage of potash are more liable to be suffering from a lack of potash than are some of the old fields which have for years received a very liberal application of this material. On these fields it is probable that there is an accumulation of potash in the soil sufficient to have carried the crop over the period of the shortage.

Organic matter, of course, can be economically applied to the soil in the form of a cover crop, as has already been mentioned, or as manure. This latter method is the more costly if all manure has to be bought, but some manure should be applied from time to time to get the best development of tobacco, apparently, although it is true that many growers are at present using commercial fertilizers and cover crops alone with good success.

The increased growth on acid phosphate in conjunction with applications of organic matter is conspicuous and rather difficult of explanation, aside from the points brought out in the discussion of the question of soil reaction. The tobacco plant uses very little of the available phosphoric acid of the soil, and certainly for direct fertilization effect, or as a food material, the plant needs only a small amount of the phosphoric acid available. It might be well to caution against the use of very large amounts of acid phosphate on our heavier soils year after year, as there is a tendency for this material to darken the leaf, and also, on account of the sulfate or sulfuric acid contained in it, to injure the burn. In our experiments, however, this has not occurred as yet.

Miscellaneous Observations.

Other Root-rots.

While making an examination of the roots of plants from a field which had presented an unthrifty appearance all season (1916), but on which very little root-rot (Thielavia) could be found, it was observed that certain of the plants showed a peculiar discoloration of the root stock just below the surface of the ground. The only organism isolated was a species of Actinomyces, which was characterized by Dr. P. J. Anderson of this department as differing, apparently, from the ordinary forms found in our soils. No connection has been established as yet between the presence of this fungus in soils and its relation to the tobacco plant. No infection experiments have been made, but a study of this organism, if found again, is projected. Forms of Fusarium were also isolated from this and other material, but their rôle is problematic.

"Mammoth" Types of Cuban and Connecticut Havana Tobacco.

From time to time there have appeared in the fields of Connecticut so-called "mammoth" plants of Cuban and Connecticut Havana tobacco. Beinhart and Hayes first experimented with the mammoth Cuban type found in Connecticut on the plantation of the Windsor Tobacco Corporation by its manager, Mr. J. B. Stewart, from whom the type takes its name, "Stewart Cuban." This mammoth type was first grown commercially in 1914, and was found to cure in a very satisfactory manner.

At present the Stewart Cuban, or a very similar mutant, is being grown not only in Connecticut, but in Massachusetts as well to a limited extent.

It apparently is also satisfactory to the trade, which is essentially the final test of all tobacco.

In 1912 and subsequently, mammoth mutants have been quite frequently found in fields of Connecticut Havana. In 1916 our attention was called to two plants in a field in Sunderland by Mr. Frank Hubbard. These plants were darker green in color and had a larger leaf than did the average plant, and showed no indication of budding when the plants in the rest of the field were ready for topping. The number of leaves per plant was also greater, and they were set much closer together on the stalk. These two plants were removed to the greenhouse early in September and allowed to mature. It was not until mid-April of the following spring that the plants blossomed, and seed could not be obtained until May.

Before transplanting to the greenhouse there were primed from these two plants thirty-eight and forty-six leaves, respectively. It was reported that these leaves cured satisfactorily. At the time of blossoming there had been produced on the main stalk of each plant one hundred and thirty and one hundred and ten leaves of sufficient size to be called marketable.

In 1918 some few hundred plants were set in two fields, one in Southwick, on the farm of Mr. C. H. Granger, and one in Sunderland, on the land of Mr. Frank Hubbard.

The comments of the growers are as follows: Mr. Granger said, "I primed forty to fifty leaves from a plant, but they never cured right, and about the only recommendation I can give this tobacco is a fine-shaped leaf and increased weight. I topped some of it but got no better results."

Mr. Hubbard reported that he was much pleased with the type and habit of growth, but that as the plants were not set on what he would consider prime tobacco land he would prefer to try it again. Some of the tobacco he had bulk-sweated, and it came through rather better than was expected. The leaf had a good body, vein, etc., but contained little or no light wrapper, consisting principally of medium and dark wrapper and binder. The taste and burn were fairly satisfactory. The yield, in comparison with the ordinary type of Havana, was approximately doubled.

Further work with this type of tobacco, looking toward improvement of quality by varying the fertilization and also a method for maturing seed earlier, is in progress. It is believed that this mammoth type of Connecticut Havana may possess commercial possibilities.

High-pressure versus Low-pressure Seed Bed Sterilization.

It has been universally recommended that in sterilizing the seed beds with steam, as high a steam pressure as possible be maintained at the boiler, usually from 75 to 125 pounds, and that the steam be allowed to act under the pan for from twenty to thirty minutes in order to insure thorough sterilization.

Low-pressure outfits developing around 20 pounds pressure have been

used, and in many instances with entirely negative results so far as killing disease-producing organisms was concerned.

It has been stated by some growers that they were absolutely sterilizing their beds with low-pressure steam in the same time as with the high-pressure outfits. There is no question but that certain types of soils will permit the use of low-pressure, providing the soil is in exactly the right mechanical condition and has a minimum water content. This has been done experimentally and practically on light porous soils, but unless the grower is assured by thermometer readings, or the complete cooking of potatoes at the desired depth, that the soil is sterile, it is apt to be a costly and futile undertaking.

It is much safer to use high-pressure outfits, particularly when the work is done by outside parties. In any event, the grower should assure himself that he is sterilizing the soil and not merely killing a few weed seeds. For general application the high-pressure method should be used; the low-pressure method will sterilize, but economically it has only a very limited range of application on certain soils. Usually there is too much guesswork in sterilization.

Vitality of Tobacco Seed.

It has been generally believed that the seed of tobacco retains its vitality for a number of years, even up to twenty. This may be true in exceptional cases in which the seed has been preserved under ideal conditions, but usually after the tenth year the vitality of our seed is so much reduced as to render it unfit for use, even when preserved under the best conditions.

A grower, however, often wishes to use a particular lot of seed a number of years, and it is of interest to know approximately, at least, what the germination of seed of the different varieties is at different ages. The maintenance of vitality, of course, depends to a great extent on the conditions under which the seed is kept, and this factor should be taken into consideration in drawing conclusions as to the germinability of the seed. In the following table are given some of the results obtained with seed of different ages kept under excellent conditions in a cool, dry place, either in muslin bags or wide-mouthed glass containers plugged with cotton: —

TABLE VIII. — *The Vitality of Tobacco Seed of Three Varieties preserved properly for Various Lengths of Time.*

Variety.	Age of Seed (Years).	Test No.	Per Cent of Germination at Two-day Intervals.						Average.
			2	4	6	8	10	12	
Broadleaf,	10	1	0	0	0	0	16	45	50
		1*a*	0	0	0	0	12	55	
	9	2	0	0	0	12	21	67	66
		2*a*	0	0	0	0	16	65	
	5	3	0	0	58	89	95	95	95.5
		3*a*	0	0	62	92	96	96	
	2	4	0	0	60	85	88	90	91.5
		4*a*	0	0	54	80	91	93	
Havana,	37	5	0	0	0	0	0	0	0
		5*a*	0	0	0	0	0	0	
	25	6	0	0	0	0	0	0	0
		6*a*	0	0	0	0	0	0	
	9	7	0	0	0	0	0	2	1.5
		7*a*	0	0	0	0	0	1	
	6	8	0	0	61	68	–	–	68
		8*a*	0	0	58	68	–	–	
	4	9	0	–	–	95	–	96	95.5
		9*a*	0	–	–	92	–	95	
	2	10	0	0	–	–	98	98	99
		10*a*	0	0	–	–	100	100	
Cuban,	6	11	0	0	8	22	41	54	49.5
		11*a*	0	0	18	35	41	45	
	4	12	0	0	23	74	88	–	82
		12*a*	0	0	31	66	84	–	
	2	13	0	0	27	86	91	–	93
		13*a*	0	0	28	90	95	–	

Considerable variation will be noted in the above table, and perhaps a larger series would have changed the results somewhat, but it was impossible to find seed saved under these conditions. The results at least serve as an indicator of the probable vitality of these varieties. The Broadleaf variety apparently retains its vitality longer than either the Havana or Cuban.

A few samples from tin cans and corked bottles were germinated at the same time with the following results: —

Five-year-old Broadleaf germinated only 31 per cent.
Three-year-old Broadleaf germinated only 72 per cent.
Two-year-old Havana germinated only 87 per cent.

Seed should be thoroughly dry when placed in containers, and some means of ventilation, or better, aëration, should be provided; otherwise the accumulation of moisture in the containers will be very conducive to

mold growth. Seed preserved in cloth bags in a cool, dry place will retain its vitality longer, and give higher percentage of germination, than seed stored in air-tight containers.

Top-dressing Tobacco Seed Beds with Dry Ground Fish.

It is the custom of many growers to top-dress the tobacco seed beds occasionally with some quick nitrogen fertilizer, such as ammonium sulfate, nitrate of soda, commercial "starter," or fish. The danger of using an excess of the three former is pretty well recognized by the growers, but in the use of dry ground fish not so much attention has been paid to the amount used, as it has been claimed that it is impossible to apply an excess of this material.

This view is erroneous, as at least three cases have been noted where an excess has been applied, the "burning" of the plants taking place four to six days after application. In all cases the plants were thoroughly sprayed and the fish well washed off the leaves. Experimentally, the same applications proved injurious in all three cases. The mechanical condition of the fish seems to play a very important part in the injury, as in all three cases the fish was very finely ground, and in all probability the nitrogen was more quickly available than with other coarser or less nitrogenous fish.

No set rule as to the amount to be applied can be given, but as much discretion should be used with fish as with the ammonium sulfate or sodium nitrate, as the loss of the beds from top-dressing is a very serious matter.

As a matter of fact, beds properly fertilized should not need any application of nitrogen except, perhaps, after they have been pulled over several times. While a large, apparently vigorous growth is obtained when the bed is repeatedly top-dressed with nitrogenous fertilizers, the plants are apt to be tender and succulent, and will not stand transplanting so well.

Summary.

1. *The yield of tobacco in Massachusetts has not been gradually decreasing during the past ten years. Since 1914 the yield has been low, but this is due to adverse climatic conditions primarily.*

2. *In general, rainfall is the major limiting factor of growth (and this necessarily includes soil moisture along with it), together with temperature.*

3. *Excessive seasonal rainfall is invariably followed by a reduction in yield, independent of temperature.*

4. *Subnormal rainfall, when accompanied by temperatures excessively above normal, reduces the yield.*

5. *Subnormal rainfall, when accompanied by subnormal temperatures, does not apparently reduce the yield to any extent unless the rainfall is very much below normal.*

6. *There are, undoubtedly, in many localities specific problems to be worked on, such as the effects of improper fertilization, methods of culture, and control*

of disease-producing organisms; but these are "specific" and not "general" troubles as yet.

7. *The tobacco soils of Massachusetts fall into three groups, as regards acidity or "lime requirement." Soils with a "lime requirement" up to 3,000 pounds CaO per acre are not producing good crops, as a rule, and are comparatively free from root-rots. Those with a "lime requirement" of from 3,000 to 8,000 pounds CaO per acre are in good tobacco condition; but in this group pathogenic fungi are abundant in the soil, and the plants, during certain seasons, are very liable to suffer from root-rots caused by some of these fungi. Soils with a "lime requirement" of 8,000 pounds CaO up are usually comparatively free from such fungi, and even in unfavorable seasons little disease is found, but the tobacco is perhaps of slightly inferior quality.*

8. *Most of the tobacco soils in Massachusetts are deficient in humus or organic matter.*

9. *To supply this lack of organic matter cover crops, preferably timothy, should be planted and plowed under.*

10. *No satisfactory field soil treatment for the Thielavia root-rot has been worked out.*

11. *Many of the so-called "sick" soils are responding favorably to additional applications of organic matter and phosphoric acid in the form of acid phosphate. Care should be exercised in the application of these materials to guard against excess.*

12. *Our fields, generally, are not yet suffering from a lack of potash, as determined by plant growth and development.*

BULLETIN No. 196.

DEPARTMENT OF AGRICULTURE.

METHODS OF APPLYING MANURE.

BY WM. P. BROOKS.

Introduction.

The question as to the best system of handling and applying manures is one which has always excited a great deal of interest, and is of very special importance at this time. The reasons which have given the question exceptional importance in recent years are several. Among the more prominent are these: —

1. The increasing insistence, on the part of those using the product of our dairy stock, not only that manure shall not be stored, as was formerly the custom, in a cellar beneath the stable, but that it shall be promptly taken away from the vicinity of the stable.

2. The increasing cost of the labor of taking manure from the stable to the fields where it is to be used.

There are, of course, great possibilities of variation in methods adopted, but one of the most prominent in the minds of those making use of manure has been the question as to whether, when removed from stable or other place where it has accumulated, it is advisable to spread it at once upon the land, irrespective of the season of the year when it must be so removed, or whether provision should be made to store it in some manner and hold it until it can be incorporated with the soil. This has always been a question upon which there has been a great difference of opinion, both plans having earnest advocates, especially the plan of spreading manure as fast as it must be moved, on account of reduced cost of labor connected with its application under that system, and reduction of the pressure of farm work in the spring. The experiment described in the following pages was planned with a view to throwing light upon this question.

The experiment began in 1900. The land available for use in the experiment lay on a moderate slope from the east toward the west, which was fairly uniform, though not quite ideal in respect to uniformity, and which lay at an angle with horizontal of about $4\frac{1}{2}$ degrees. The location

is near the foot of the west side of a drumlin of moderate elevation. According to a soil survey made by the United States Department of Agriculture the soil is of that type for which the name Holyoke Stony Loam was suggested. It is a type of soil which with minor variations is very common throughout Massachusetts, and is known in the ordinary language of the farm as a moderately strong gravelly loam, with good capacity for retaining and conducting moisture, and somewhat affected, more or less unevenly as is pointed out in another connection, by seepage water which tends toward the surface from the higher portions of the drumlin as it finds its way downwards.

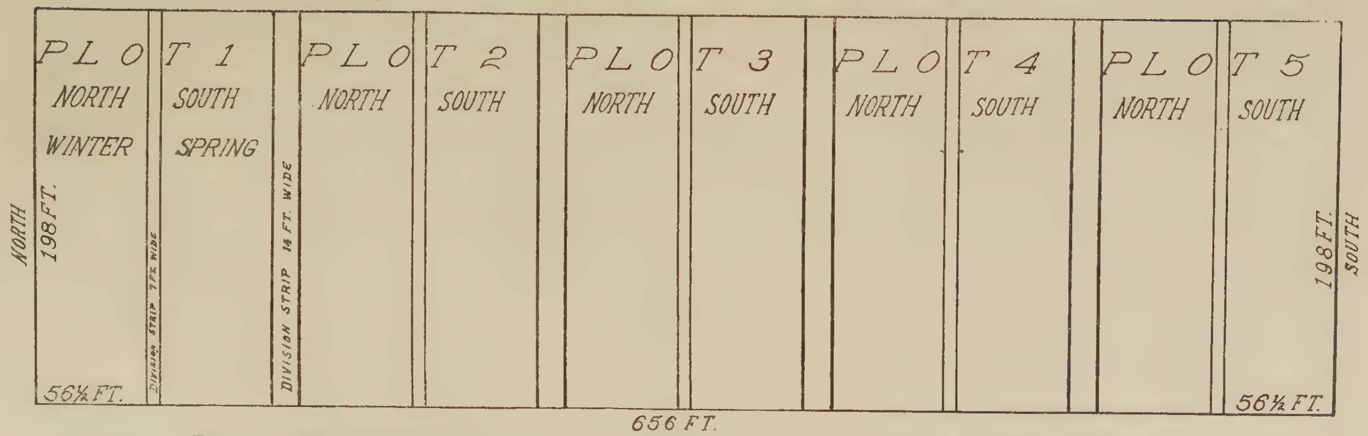
The land referred to had been used in an orchard experiment designed to test the relative results of different systems of manuring continuously followed from the year previous to the setting of the nursery stock. The kinds of fruit which had been used in the orchard experiment were peaches and pears. The land used was divided into five equal plots, each of which was uniformly manured annually from 1889 (the year previous to the setting of the trees) until 1897, both inclusive. As already indicated, the trees were set in 1890. The land proved unsuited to the peach and pear, a number of the trees died quite early in the experiment, and, since the number lost in different plots differed widely, it was decided to be inexpedient to continue the experiment with these kinds of fruit. Both manure and fertilizers used while the land was in fruit were applied broadcast in the early spring.

Plan of the Experiment.

The statements concerning the history of the area used in the experiment to be described have made it apparent that we had available five plots lying side by side upon a fairly even slope which had been respectively subjected to a widely varying fertilizer treatment. It is at once apparent that results on these plots could not be compared one with the other in such a way as to throw any light upon the question of the relative effects of different methods of applying manure. Accordingly each of the original orchard plots was divided in the middle by a line running directly up and down the slope. The different original plots were separated by unmanured or fertilized strips of land 14 feet wide, while the two halves of each of the original plots as laid out for the experiment under discussion were separated by a strip 7 feet in width. For purposes of record it was decided to retain the original orchard plot numbers, and to make the application of manure to the north half of each plot in winter, that to the south half in spring. The system followed to insure as closely as possible absolute equality in amount and kind of manure applied to north and south plots was as follows: —

All the manure used on plots 1 to 4, both north and south halves, was the product of the experiment station herd of milch cows. These cows were liberally bedded with baled planer shavings. The floor upon which the cows were kept was watertight, and the manure was removed at

PLAN OF PLOTS. MANURING EXPERIMENT.



FERTILIZER TREATMENT, 1889–97.

Plot 1, manure, 10 tons per acre.
Plot 2, wood ashes, 1 ton per acre.
Plot 3, nothing.
Plot 4, ground bone, 600 pounds per acre; muriate of potash, 200 pounds per acre.
Plot 5, ground bone, 600 pounds per acre; low-grade sulfate of potash, 400 pounds per acre.

MANURING EXPERIMENT, 1900–19.

Manure applied annually, 1900–11 (with the exception of 1907), at the rate of 10 tons per acre.
North half, winter application.
South half, spring application.
Plots 1 to 4, cow manure; plot 5, horse manure.
Plot 1, early winter; plot 4, late winter.
No manure applied since 1911.

least twice daily to concrete pits, watertight and roofed. There were two pits. Manure was allowed to accumulate in the pits until the amount was sufficient to supply the needed quantity for an entire plot. The manure was then conveyed to the field, being weighed load by load as it was moved. (In referring to the different plots, the north half will be designated as "N," and the south half as "S." The arrangement and previous history will be understood by reference to the plan, page 41.)

The first load of manure was spread on plot N; the second load taken out was dumped into the foundation of a heap to be built out of the manure which was to be spread in the spring (this being located on some part of plot S, differing from year to year). Alternating loads were taken, respectively, to N and S, and either spread on N or added to the heap on S. The total weight when removed from the pits to the field as described was the same for both N and S. The annual application was at the rate of 20 tons per acre.[1] In building the heap on S, it was the practice to drive over what had previously been dumped as long as possible; and when all the manure had been taken out, the heap was squared up and was usually about 4 or 5 feet in height, with sides nearly perpendicular. In other words, the manure was so piled as to expose it as little as possible to danger of loss through washing and leaching. As has been indicated, care was taken in successive years to place the heap of manure on the different plots S on different parts of the plot, in order to equalize as far as possible any effect due to leaching of material directly from the heap into the soil beneath and in its immediate vicinity. Manure held in heaps from the time it was hauled out until spring was in all cases allowed to stand in the heap, when a hoed crop was to follow, until the soil could be worked. It was then spread on the plot on which the heap stood as evenly as possible, and then the entire area, including that to which manure had been applied during the winter, was disked, thus at once mixing the newly spread manure with the soil. When the land was in grass the time of handling the manure from the heap was practically the same as when the land was to be put into a hoed crop, and after spreading the manure from the heap upon the mowing it was the usual practice to go over the entire area, winter as well as spring applications, with a brush, for the purpose of fining and promoting a more even distribution of the manure. The manure held in heaps on all plots was almost invariably all spread in each year on the same day, or, if conditions rendered this impossible, the work once begun was completed at the earliest possible moment.

When the land was to be put into a hoed crop the following year, it was either sown to a cover crop of rye the previous fall or plowed late in the fall across the slope of the field. No attempt was made to vary the date of application according to variations in the field conditions as regards covering with ice or snow or freedom therefrom, and any one

[1] A cord of undecomposed, well-saved cow manure from animals moderately bedded with planer shavings weighs about 3 tons.

familiar with the New England climate will understand that there was very wide variation in conditions at the time of application. Plots N and S on plot 1 were the first plots supplied with manure except in 1911, when the order was reversed. With the exception of the year just named, plots 2, 3 and 4 were supplied in the order named. The application to plot 4 was therefore, with one exception, either very late in the winter or in the early spring.

TABLE I. — *Variations in Date of Application of Manure and of Spreading from Heaps.*

Plot.	North Half.		South Half.			
	Spread.		Piled.		Spread.	
	Earliest.	Latest.	Earliest.	Latest.	Earliest.	Latest.
1, ...	Nov. 19	Mar. 13	Nov. 19	Mar. 13	Apr. 4	May 23
2, ...	Nov. 24	Feb. 26	Nov. 24	Feb. 26	Apr. 4	May 23
3, ...	Dec. 16	Mar. 31	Dec. 16	Mar. 31	Apr. 4	May 23
4, ...	Dec. 16	Mar. 28	Dec. 16	Mar. 28	Apr. 20	May 23
5, ...	Dec. 9	Mar. 8	Dec. 9	Mar. 8	Apr. 4	May 25

The manure applied to plot 5 was of different character. It was obtained from a local livery stable, and was horse manure usually comparatively fresh and containing a moderate amount of straw which had been used for litter. In supplying manure to N and S of plot 5, the plan described in outline for the other plots was followed; that is, alternate loads respectively spread on N and added to a heap on S, the total to N and S being the same for each.

In 1906 the whole field received an application of hydrated lime at the rate of 1 ton per acre. This was applied on the rough furrow and was worked in by the use of the disk harrow.

The experimental system of manuring described was continued annually from 1900 to 1911, both inclusive, with the exception of one year, 1907, when no manure was applied to any plot, and with a few minor variations which seem unimportant in their relation to the results obtained. In preparation for the experiment, the yield of all plots in the field under precisely similar manurial treatment for all was determined in 1899. In this year manure from the station herd of dairy cows was applied by means of the manure spreader driven transversely across all the plots in moderate and in precisely equal amounts to each, as nearly as careful regulation of the machine permitted. The field was planted with corn. There was considerable difference in the total yield of dry matter obtained on N and on S of plot 3, which reference to the plan (page 41) shows was the plot which during the continuance of the orchard experi-

ment had been neither manured nor fertilized. These yields are shown in Table II, as also are the yields of dry matter in 1899 on all the other plots.

TABLE II. — *Dry Matter per Plot after Uniform Manuring in 1899. Ensilage Corn (Pounds per Plot).*

PLOT.	North Half.	South Half.
1,	1,559	1,660
2,	1,758	1,696
3,	756	1,271
4,	1,659	1,551
5,	1,616	1,703

It will be noted that there is but little variation in yield between N and S on the other different original plots, the extreme range being from 1,550 to 1,750 pounds. The results obtained, therefore, indicate that the conditions for the comparison of the two systems of applying manure were fairly satisfactory.

I would, however, call attention to the fact that probably more important than variations in fertility dependent upon differences in plant-food content were differences in moisture conditions on the different plots. The slope used in the experiment lay upon the west side of a drumlin, a geological formation extremely common and highly important in the agriculture of Massachusetts. As is likely to be the case with slopes on drumlins there is a tendency for seepage water, which sinks into the soil farther up on the slope or on the summit, to work outward toward the surface on the lower parts of the slope. During some years and with some crops this movement of soil water exerted comparatively little effect on the crop, but there can be no doubt that in seasons of comparatively heavy rainfall during the period of most active growth, especially of crops such as corn and soy beans which require high soil temperature for best results, it was sufficient on some of the plots to keep the soil cooler and wetter than is desirable for the best yields.

RELATIVE EFFECTS OF THE TWO SYSTEMS OF MANURING ON CROP YIELDS.

Table III shows the crops grown in successive years during the period of the experiment under consideration, and for each year indicates in how many of the five different comparisons either N or S, or one of them alone, gave the larger yields. Attention is called to the fact that the period during which manure was applied annually in accordance with the two plans under comparison was twelve years, and that there were five comparisons each year, or 60 in all.

TABLE III. — *Manuring Experiment, General Character of Results.*

Year.	Crop.	North Half ahead.	South Half ahead.
1900,	Corn (grain),	1	4
1901,	Millet,	–	5
1902,	Corn (ensilage),	2	3
1903,	Soy beans, beans,	3	2
1904,	Corn and soy beans (ensilage),	3	2
1905,	Corn (grain),	–	5
1906,	Corn (grain),	1	4
1907,	Mixed grass and clover,	2	3
1908,	Mixed grass and clover,	–	5
1909,	Mixed grass and clover,	3	2
1910,	Mixed grass and clover,	–	5
1911,	Mixed grass and clover,	4	1
	Totals,	19	41

Examination of this table shows that, as might be expected by any one familiar with the variations in our climate, results were not consistently favorable throughout the entire period, either to one or the other season of application; but the general average result was most favorable to winter application in 19 out of 60 comparisons, or practically 1 in 3.

The following points appear to be worthy of especial mention. In 1903, the crop being soy beans, the general average based upon results upon all the plots showed that plots N were ahead both in yields of beans and straw. In 1904, the crop being corn and soy beans which were ensiled, the crops were about equal. When the crop was mixed grass and clover the general average was favorable to the North half three years out of five, or in three-fifths of the trials. On the other hand, when corn for ripened grain was the crop, the South half was invariably ahead on the general average.

The general results, therefore, it may be said, appear to indicate that the common practice of top-dressing mowings with manure during the late fall or winter rather than in the spring is wise. If, however, we study Table IV, which shows the percentage results, it will be noticed that the average superiority of the North half is due to the fact that the first, or hay, crop is usually the better under that plan; the rowen crop, on the other hand, is usually better when the manure is spread in the spring, and the degree of superiority as indicated by the higher percentage shown in Table IV for the rowen crop under spring application is usually very high.

TABLE IV. — *Manuring Experiment, Percentage Results.*

Year.	Crop.		Percentage for South Half (North Half=100 Per Cent). Plot 1.	Plot 2.	Plot 3.	Plot 4.	Plot 5.
1900	Corn,	Grain,	96.3	108.6	124.7	111.1	132.6
		Stover,	113.2	105.2	125.5	108.9	111.4
1901	Millet,		118.2	131.3	177.0	145.7	148.7
1902	Corn (ensilage),		103.9	97.3	150.0	91.6	108.6
1903	Soy beans,	Beans,	106.9	95.3	95.9	82.5	106.7
		Straw,	118.7	103.7	90.8	81.4	101.4
1904	Corn and soy beans,		92.2	107.4	130.1	92.9	97.2
1905	Corn,	Grain,	102.1	123.6	123.1	119.5	106.4
		Stover,	107.0	108.6	113.3	111.6	105.1
1906	Corn,	Grain,	105.9	122.9	108.4	93.2	102.2
		Stover,	105.9	114.0	107.9	99.1	100.2
1907[1]	Mixed grass and clover,	Hay,	100.3	98.7	107.0	92.9	95.2
		Rowen,	111.1	90.0	87.3	105.6	174.2
		Total,	101.6	97.3	103.5	94.5	101.6
1908	Mixed grass and clover,	Hay,	111.1	116.0	118.8	113.0	93.2
		Rowen,	113.1	115.7	111.8	86.7	143.8
		Total,	111.5	115.9	117.8	108.7	100.7
1909	Mixed grass and clover,	Hay,	81.4	99.4	105.6	86.1	92.0
		Rowen,	244.9	57.5	143.0	123.6	255.7
		Total,	85.7	95.1	107.3	88.7	102.1
1910	Mixed grass and clover,	Hay,	109.7	109.2	98.6	104.4	95.8
		Rowen,	188.9	90.6	131.6	141.0	168.1
		Total,	115.9	106.5	102.0	107.4	102.6
1911	Mixed grass and clover,	Hay,	107.6	101.2	94.6	96.3	104.2
		Rowen,	68.9	45.9	87.4	100.0	94.2
		Total,	100.0	94.1	94.2	96.4	101.5

[1] No manure was applied to either N or S on any of the plots in 1907, the reason being that the growth and general condition of the several plots which had been seeded in the corn in 1906 indicated a high degree of probability that should manure be applied the crop would lodge to a very serious extent. That the decision was wise was indicated by the results, for the crop even without top-dressing lodged considerably. The rate of yield on all plots was considerably in excess of 3 tons per acre for the first crop, and about one-half ton for the second crop on winter application, and considerably in excess of one-half ton where the manure in previous years had been applied in the spring.

Table V shows the rainfall in inches in each of the months of what may be called the growing season, together with the total for the several years. A study of the figures for the several months in the different years and the totals for these years has not sufficed to indicate any well-defined relation between rainfall and the relative standing of N and S. This, perhaps, is not surprising, because conditions affecting the amount of evaporation or loss of moisture from the land surface vary very widely in different years, especially important in this connection being the amount of sunshine, the mean temperature and the direction and amount of wind movement. The fact is we do not know them with sufficient accuracy to determine whether variations in local climate were sufficient to account for the differing results in the different years during which the experiment continued or to enable us to judge how important these climatic variations may have been.

TABLE V. — *Rainfall in Inches.*

YEAR.	April.	May.	June.	July.	August.	September.	Total for Year.
1899,	1.79	1.28	4.13	4.89	2.00	7.90	41.49
1900,	1.85	3.78	3.65	4.67	4.11	3.67	51.67
1901,	5.95	6.91	.87	3.86	6.14	4.17	49.72
1902,	3.31	2.32	4.54	4.66	4.65	5.83	46.99
1903,	2.30	.48	7.79	4.64	4.92	1.66	45.45
1904,	5.73	4.55	5.35	2.62	4.09	5.45	45.30
1905,	2.56	1.28	2.86	2.63	6.47	6.26	38.80
1906,	3.25	4.95	2.82	3.45	6.42	2.59	45.45
1907,	1.98	4.02	2.36	3.87	1.44	8.74	42.27
1908,	1.97	4.35	.76	3.28	4.27	1.73	30.68
1909,	5.53	3.36	2.24	2.24	3.79	4.99	39.12
1910,	3.07	2.67	2.65	1.90	4.03	2.86	36.11
1911,	1.87	1.37	2.02	4.21	5.92	3.41	44.21
1912,	3.92	4.34	.77	2.61	3.22	2.52	38.56
1913,	3.30	4.94	.90	1.59	2.26	2.56	39.50
1914,	6.59	3.56	2.32	3.53	5.11	.52	41.83
1915,	3.99	1.20	3.00	9.13	8.28	1.37	51.58
1916,	3.69	3.21	5.34	6.85	2.49	5.08	45.61
1917,	1.83	4.13	5.27	3.36	7.06	2.42	43.56
1918,	2.78	2.47	4.01	1.84	2.22	7.00	37.47
1919,	2.37	6.20	1.09	4.17	4.81	4.25	41.42

TABLE VI. — *Average Yields.*

Crop.	Average for Five Plots. North Half.	Average for Five Plots. South Half.	Per Cent for South Half (North Half = 100 Per Cent).
Millet (1 year),	3,847 pounds	5,414 pounds	140.7
Corn, ensilage (1 year),	15,890 pounds	16,914 pounds	106.4
Soy beans (1 year), Beans,	15.07 bushels	14.61 bushels	96.9
Soy beans (1 year), Straw,	1,212 pounds	1,193 pounds	98.4
Corn and soy beans (1 year),	22,034 pounds	21,907 pounds	99.4
Corn (3 years), Grain,	37.14 bushels	41.13 bushels	110.7
Corn (3 years), Stover,	4,452 pounds	4,844 pounds	108.8
Mixed grass and clover (5 years),	7,101 pounds	7,250 pounds	102.1
Total weight of crops removed, average of five plots.	100,517 pounds	105,694 pounds	105.2

Table VII indicates the number of times out of the twelve (the total number of years during the period when manure was generally applied annually) in which the yield on N was superior to that on S.

TABLE VII. — *General Results.*

Plot.	North Half ahead —
1,	4 years out of 12
2,	5 years out of 12
3,	2 years out of 12
4,	7 years out of 12
5,	1 year out of 12

Examination of this table shows that on plot 3, S almost invariably gave the larger yield, N being superior to it only two years out of twelve. This may be explained by the greater fertility or better physical condition of S on plot 3, as shown by the yields given in Table II. On plot 5 the general superiority of S was still more marked, N giving the larger yield only one year out of twelve. It will be remembered that the manure applied to plot 5 was from horses, whereas that applied to all the other plots was from a herd of well-fed dairy cows. As has been pointed out, this stable manure was usually comparatively fresh, yet it had without doubt undergone more fermentation previous to being taken to the field than had the cow manure applied to the other plots. The effect of this greater progress toward complete disintegration at the time of spreading must have been to increase the proportion of soluble matter in the manure,

especially the proportion of soluble ammonia and nitrates. It is a conclusion which these facts render extremely probable that the winter-spread manure on plot 5 suffered greater loss than that from cows spread on the other plots.

Further, it will be remembered that the length of time during which manure on plot 1 N was exposed was greater than on plots 2 and 4, and it is probably significant that S gave yields superior to N on plots 2 and 4 more frequently than on 1, a fact which this table brings out clearly.

Varying Effect of the Systems of Manuring on the Cover Crop of Rye.

No effort was made to determine the amount of green rye turned under on the different plots, but careful observations were made on the relative condition on N and S of the several plots. Our records of such observations show that, as would naturally be expected, the growth of the cover crop of rye during the early spring on plots N was superior to that on S. As is well understood, rye grows at an extremely low temperature, and wherever the manure had been spread during the winter the cover crop of rye derived considerable advantage from it. The dates of turning the cover crop under varied quite widely in successive years, being determined in part by peculiarities of season and in part by the crop which was to follow, but the plan adopted did not, as a rule, allow a very large growth, as it was always the aim, as it should be in turning under cover or green manure crops provided the bulk of green material is considerable, to turn the crop under some little time previous to the date of planting the crop which is to follow.

Conclusions apparently justified at the End of the Period of Annual Application.

My conclusions, if based solely upon results obtained during the period of annual application of manure, must have been about as follows: —

1. The various tabulations which have been presented indicate wide variations, and do not justify sweeping conclusions as to the superiority of either one or the other of the two systems under comparison.

2. The general results, however, in my opinion, indicate quite clearly that there was considerably more wastage, which varied from year to year in amount, from manure applied to plots N than from that first piled and later spread on plots S.

3. I believe that the fact of such excess wastage from plots N would have been brought out more distinctly by comparison of results had the rate of application of manure been lower, for the results afford fairly conclusive evidence that even after such wastage as occurred the amounts

of plant food remaining in the manure applied during the winter were in many cases at least sufficient to give the maximum yields possible under the other conditions affecting the crop.

4. I believe that our results indicate that conclusions based upon relative results of the two systems of applying manure compared for a single year or for a short series of years in current farm practice are in many cases unreliable because of the fact that the rate of application has often been sufficient so that even after such losses as occurred the supply of plant food was adequate for the crop under the conditions under which it was grown.

5. Whether the results of the comparisons made would have been similar on land more nearly level is a question on which I am able simply to express a general opinion. That opinion, based upon extensive opportunities for observation of conditions existing on Massachusetts farms, is that in almost all parts of the State there is sufficient slope to the land under cultivation so that some wash over the surface during winter and consequently some transfer of soluble plant food or absolute waste must usually be expected.

Relative Lasting Effects of Winter and Spring Applications.

Manure having been applied annually, with the exception noted, under the two systems compared from 1900 to 1911, inclusive, it was thought best to continue cropping the plots for a series of years without further differing application of either manure or fertilizer to plots N and S. As a matter of fact, the only applications made to any of the plots during the period 1912–19, both inclusive, were dressings of lime applied in 1914 and again in 1917 at the rate of 1,866 pounds per acre of calcium and magnesium oxides. Different forms of lime were used on each of the plots 1, 2, 3 and 5, namely, plot 1, hydrated lime, plot 2, marl, plot 3, fine-ground limestone, and plot 5, limoid. In each case both the form and quantity of lime applied to the two halves of the original plots (N and S) were precisely the same. It would therefore seem that the lime applied cannot have any immediate bearing upon the comparison of the lasting effects of the two systems of applying manure previously used.

The crops grown in the different years now to be considered, and the yields on the several plots, are shown in Table VIII.

It will be noted that the yields on plots S are in general considerably greater than on plots N. The percentage averages for the five plots in the different years, the yields on plots N being taken as 100, are shown in Table IX, also the relative percentage standing of N and S for the several plots.

TABLE VIII. — *Yields per Acre, 1912-1919.*

Year.	Crop.	Plot 1. North.	Plot 1. South.	Plot 2. North.	Plot 2. South.	Plot 3. North.	Plot 3. South.	Plot 4. North.	Plot 4. South.	Plot 5. North.	Plot 5. South.
1912	Mixed grass and clover (pounds),	5,857	6,391	5,679	7,618	6,114	6,569	4,946	5,144	6,866	6,984
1913	Mixed grass and clover (pounds),	4,776	5,698	4,808	5,105	4,373	4,511	3,680	3,700	5,203	4,887
1914	Soy beans (ensilage) (pounds),	13,395	13,989	13,870	13,605	10,162	9,612	9,331	9,169	10,008	10,867
1915	Soy beans, Beans (bushels),	29.9	32.5	27.3	32.7	26.3	33.7	28.0	29.7	34.2	36.3
	Soy beans, Straw (pounds),	2,541	2,427	2,376	2,494	2,075	2,642	2,271	2,275	3,061	3,357
1916	Corn, Grain (bushels),	53.3	67.2	44.1	62.7	36.7	64.7	44.7	51.7	60.7	56.8
	Corn, Stover (pounds),	3,463	4,650	2,849	4,828	2,275	4,393	2,236	3,680	4,432	5,303
1917	Corn, Grain (bushels),	37.6	58.4	37.8	49.9	28.7	51.0	39.1	45.3	56.7	51.9
	Corn, Stover (pounds),	2,790	4,551	2,078	3,957	1,919	3,878	2,770	3,621	4,333	4,690
1918	Mixed grass and clover (pounds),	2,572	3,265	3,245	3,324	3,166	2,711	2,117	2,623	2,691	4,056
1919	Mixed grass and clover (pounds),	2,513	5,224	4,076	5,144	1,662	3,364	2,157	3,482	3,977	4,630

TABLE IX. — *Percentage Results.*

Year.	Crop.	Percentages for South Half (North Half = 100 Per Cent).					
		Plot 1.	Plot 2.	Plot 3.	Plot 4.	Plot 5.	Average of Five Plots.
1912	Mixed grass and clover, . .	109.2	134.1	107.4	104.0	101.7	111.0
1913	Mixed grass and clover, . .	119.3	106.2	103.2	100.6	93.9	104.6
1914	Soy beans (ensilage), . . .	104.4	98.1	94.6	98.3	108.6	100.8
1915	Soy beans, Beans, . . .	108.9	120.1	128.1	105.8	106.0	113.2
	Soy beans, Straw, . . .	95.5	105.0	127.3	100.2	109.7	107.0
1916	Corn, Grain, ...	127.8	146.3	185.1	118.5	93.5	126.6
	Corn, Stover, ...	134.3	169.5	193.1	164.6	119.6	149.8
1917	Corn, Grain, ...	164.5	140.2	192.0	124.8	91.8	128.4
	Corn, Stover, ...	163.1	190.4	202.1	130.7	108.2	149.0
1918	Mixed grass and clover, . .	126.9	102.4	85.6	124.3	150.7	115.9
1919	Mixed grass and clover, . .	207.9	126.2	202.4	161.5	116.4	151.8

The general percentage average for plots 1, 2, 4 and 5 for the entire period 1912–19, inclusive, N being taken as 100, is 122.3 for S, while for plot 3 a similar comparison shows the standing of S to be 138.2.

The figures presented in the different tables bring out the fact very clearly that the lasting effect of manure piled when taken to the field and spread in the spring is much greater than that of manure spread in the winter. For confirmation of the fact just stated, the reader should compare the figures given in Table IX with those in Tables VI and VII, which refer to the period during which manure was applied annually.

The figures for successive years presented in Tables VIII and IX indicate clearly that the superiority of plots S as compared with plots N as yet shows no signs of diminution. On the contrary, it is considerably greater during the later years of the period under consideration than in the earlier. This is most clearly shown in the last column of Table IX, which gives the percentage averages of the five plots; thus, for example, during the first and second years of the period under consideration, plots S in mixed grass and clover showed a percentage superiority of 111.0 and 104.6; in the last two years; 1918 and 1919, corresponding figures were 115.9 and 151.8. A similar relation is shown between the percentage advantage of plots S in 1915 as compared with 1914, soy beans being the crop; and in 1917 as compared with 1916, corn being the crop. This advantage in the case of the corn crop is less than with the others.

Effect of the Two Systems previously followed in the Application of Manure on Growth during the Early Part of the Season and the Maturing of the Crop.

From the very first year of the period under consideration, 1912–19, it was noticed that much earlier and more vigorous growth took place on plots S than on plots N. Whatever the crop, the superiority of S was clearly shown by better color and more rapid advancement. It would have been a matter of great difficulty to determine the difference in amount of growth made at any given period by measurement, but the field was under constant careful observation, and my own judgment I feel sure is accurate. When corn was the crop, I should say that by the last of June or the first of July the average height of the plants on plots S was some 3 or 4 inches greater than on plots N. When the field was in mixed grass and clover, the degree of superiority was in my judgment about the same, and indicated in inches would, I think, equal about 3 inches by the first of June. The earlier maturity of the crops on plots S also clearly indicates an earlier start and more rapid progress. This is shown most conclusively by the figures in Table X, showing the relative proportions of hard and soft corn at the time of husking.

Table X. — *Effect on Ripening Corn (Pounds per Plot).*

Plot.	1916.				1917.			
	North Half.		South Half.		North Half.		South Half.	
	Hard.	Soft.	Hard.	Soft.	Hard.	Soft.	Hard.	Soft.
1, ...	915	29	1,170	19	700	60	1,150	30
2, ...	745	35½	1,090	19	700	64	980	29
3, ...	605	45	1,120	25	505	75	970	60
4, ...	755	35	895	20	710	80	885	30
5, ...	1,055	20	985	20	1,115	30	1,025	25

It will be noted that plot 5 is an exception to the general rule that the proportion of hard corn is considerably greater on plots S than on plots N. A considerable number of my different experiments, confirmed, I believe, as a rule, by the experiments of others, indicates that the period of ripening is affected more by the supply of phosphoric acid in highly available form than by any other plant-food constituent. An excessive supply of potash or of nitrogen does not, I believe, favor early ripening, but quite the contrary, unless there be a very liberal supply of phosphoric acid. It seems to me highly probable that the relative high standing of plot N on 5 in the proportion of hard corn is connected with the fact, which is generally known, that the proportion of phosphoric acid in manure from horses is higher, as a rule, than in that from milch cows,

but I desire to point out that a little variation in level and character of soil from the north to south perhaps helps to account for the relatively high standing of N on plot 5.

We have yet, however, to consider how the superiority of S on the other plots, 1, 2, 3, and 4, can be accounted for. It seems to me possible that variation in humus content produced by the different methods of handling the manure and consequent differences in soil temperatures or in biological activities going on in the soil may to some extent have influenced the results. I believe, however, that more important than these is probably this fact, which, as was pointed out again and again by Paul Wagner in connection with his different experiments a considerable number of years ago, had an important connection with results.[1] Wagner pointed out that in northern latitudes optimum weather conditions for growth may exist during only a small proportion of the so-called growing season. This fact is generally recognized. All those familiar with agriculture in Massachusetts understand that, especially for crops flourishing at high temperatures and to a considerable extent for others also, weather conditions during some part of the growing season are unfavorable to rapid progress. It is often too wet or too dry, or it may be too cold, and rather exceptionally too hot when the high temperature is coincident with shortage in supply of moisture. When optimum weather conditions come, then the plant is capable of extremely rapid growth, provided the other factors essential for such growth exist, and among such other factors an abundant supply of plant food is one of the most important. Where the supply of plant food is comparatively low or meager the crop may become a good one if the weather and other conditions for growth are favorable throughout the greater part of the growing season, but, in proportion as the best of weather exists only a portion of the time, the crop will come to rapid maturity only where it finds a great abundance of food. Considerable wastage evidently occurred where the manure was spread in the winter. It is clear, therefore, that the supply of food, and hence this one among the several factors essential to rapid progress when the weather conditions are right was found in highest degree on plots S. It has long been recognized that the farmer or gardener who works his land intensively (under which term in this connection I refer particularly to an abundant supply of available plant food) is less unfavorably influenced by bad weather than the farmer or gardener whose soils are relatively low in available plant food or poorly worked.

The Relative Effects of the Two Systems on the Proportion of Clover in Mixed Mowings.

Whenever the plots used in this experiment were put into mowing, a mixture of timothy, red top and medium and alsike clovers was sown. The field was in mowing in 1912 and 1913, the first two years of the period under consideration, and it was noted that the proportion of

[1] Paul Wagner: Zur Kali-Phosphat-Düngung nach Schultz-Lupitz, Darmstadt, 1889, s. 18 u. a.

FIG. 1.—Plot 1, north half, from photograph taken Aug. 7, 1919.

FIG. 2.—Plot 1, south half, from photograph taken Aug 7, 1919.

clovers on plots S was considerably greater than on plots N. The distribution of clovers in the different plots was not entirely uniform, some variations being apparently due to differences in moisture conditions. No photographs were taken during these two years, and the fact stated is demonstrated principally by the greater superiority of the rowen crop (made up chiefly of clovers) on plots S than of the first crop on the same plots.

The plots were put into mowing again in 1918, the seed having been sown, as is customary in this part of the State and with the type of soil on which the experiments were located, in the standing corn about the time it was waist high in 1917. We have harvested the hay crops now for two years, and Figs. 1 and 2 were made from photographs taken on Aug. 7, 1919, by a station assistant, R. L. Coffin. The difference in the proportion of clover, it will be seen at once, is very striking. The proportions of grasses and clovers on different parts of the several plots were not entirely uniform either on single plots N and S, under comparison, or on different pairs, and the excess of clover was not as great everywhere as indicated by the illustrations.

With a view to indicating in words as clearly as possible the different conditions, notes were taken on June 17, 1918, by a very careful station assistant, Mr. R. L. Coffin. I quote from Mr. Coffin: —

Plot 1. N, very little clover, mostly red.
S, seven-eighths clover, red and alsike about evenly divided.
Plot 2. N, seven-eighths clover, mostly alsike, but more red than on plot 5.
S, over seven-eighths clover, practically a dense mass of clover, more red than alsike.
Plot 3. N, almost no clover, but a little both red and alsike present.
S, nearly seven-eighths clover, more red than alsike.
Plot 4. N, about one-fourth clover, mostly alsike; a little sorrel.
S, nearly seven-eighths clover, mostly alsike; a little sorrel. Growth on plot 4 not as heavy as on plot 5.
Plot 5. N, seven-eighths clover, mostly alsike.
S, a little more clover than on N. Except for two small areas, a dense mass of clover, mostly alsike.
General condition on all plots: heads just beginning to show on timothy and red top, the proportion of red top being apparently somewhat greater than that of timothy.

Why Clover has been more abundant on Plots S.

The facts which have been for a long time known concerning the proportions of the different leading plant-food constituents and their degree of solubility in manures appear to the writer to have indicated in advance the more important wastes likely to occur from manure spread during the winter and allowed to remain upon the surface. The more important of these facts which seem to have a bearing upon the results are as follows: —

In fresh, well-made cow manure the proportion of its nitrogen content soluble is about one-third of the whole; the proportion of its potash con-

tent soluble is about four-fifths of the whole; while practically all of the phosphoric acid is insoluble. In the case of the plots, then, to which cow manure was applied in winter, one must have anticipated that such waste as occurred would have carried off more potash than of either of the other more important elements. In the case of the stable manure applied to plot 5, as has already been pointed out, some fermentation had taken place before it was taken to the field. This must have increased the solubility of the nitrogen content, but this manure, it will be remembered, was from horses, and such manure is much drier than fresh cow manure, the urine being relatively far less abundant. This must, I think, decrease the probability of a loss of potash from manure spread during the winter. Moreover, the application made to plot 5 was usually comparatively late in the winter, so that the period of exposure on the surface was shorter than the average of the other plots, which also would tend to decrease the amount of such loss of potash as may have occurred.

It is now a matter of almost universal knowledge that the proportion of clover in mowings is much affected, throughout the greater part of the soils of Massachusetts at least, if not throughout those of the greater part of the northeastern section of the United States, by the supply of potash in available form; and the much greater proportion of clover on plots S than on plots N of 1, 2, 3 and 4 tends to confirm my opinion in a striking way, — that the greatest loss which occurred from manure spread upon the surface in the winter and allowed to remain there until spring was the loss of potash. The fact that there was less difference in the proportion of clover on N and S of plot 5 than on the other plots tends also to confirm the correctness of the opinion expressed concerning the losses from the partially fermented stable manure.

Just how great may have been the losses of nitrogen from manure spread in the winter and allowed to remain on the surface, our figures showing yields fail to give a very complete index; but the fact that in the eighth year without additional manure the yield of hay even on plots N was, in general, good shows that the wastage of nitrogen was probably not very excessive. Nor would excessive loss of this element, as a rule, be reasonably expected, in view of the fact that the manure spread in the winter on most of the plots was practically entirely unfermented, and could not under normal winter weather conditions undergo fermentation while lying upon the surface, which would increase the solubility of the nitrogen compounds found in the fresh manure.

Financial Results.

The basis of the calculations upon which the tables presenting relative financial results have been computed is as follows: Value of products per ton: millet hay, $10; mixed grass and clover hay, $12; rowen, $8; ensilage corn, $4; corn and soy bean mixture for ensilage, $4; soy beans for ensilage, $5; corn stover, $6; soy bean straw, $5. Value per bushel: corn, 70 cents (1 cent per pound on the ear); soy beans, $2.50. The

calculation was made on the basis of the average for the five pairs of plots N and S, and the area for which results are computed is 1 acre. The excess cost of handling manure where it was piled when hauled out and spread in the spring has been estimated at $2 per acre where the work is done upon a large scale, for on such scale the manure spreader would be used in applying the manure from the heaps in the spring, whereas conditions when manure is hauled out and applied during the winter are by no means always such in our climate as to make the use of the manure spreader practicable. It is believed, therefore, that the figure taken — $2 per acre — is sufficient to represent the difference in cost under conditions existing on farms of sufficient size to justify the use of the spreader.

The same values have been used in the calculations throughout the entire period covered by the two tables, although prices during the past four or five years have advanced materially, so that the figures taken as applied to these years are considerably too low. The reader will perhaps at once think that so also must be the figure representing the difference in the cost of handling the manure; but in this connection it is important to remember that during the past eight years no manure has been applied to any of the plots, so that the question of the excess cost of handling does not affect the results as presented in Table XII.

TABLE XI. — *Calculated Results per Acre for the Period of Annual Application of Manure.*

Crop.	Crop Values, Yearly Average. Difference in Favor of —		Cost of Application of Manure. Difference in Favor of —	Total Yearly Average. Difference in Favor of —		Number of Years.	Total Difference in Favor of —	
	Winter (N).	Spring (S).	Winter (N).	Winter (N).	Spring (S).		Winter (N).	Spring (S).
Millet,	–	$7 83	$2 00	–	$5 83	1	–	$5 83
Soy beans,	$1 20	–	2 00	$3 20	–	1	$3 20	–
Corn,	–	3 97	2 00	–	1 97	3	–	5 91
Mixed grass and clover,	–	66	2 00	1 34	–	5	4 70[1]	–
Corn (ensilage),	–	2 05	2 00	–	05	1	–	05
Corn and soy beans (ensilage).	25	–	2 00	2 25	–	1	2 25	–
Total,	–	–	–	–	–	12	$10 15	$11 79

Balance in favor of spring, $1.64.
Average for 1 year, $0.14.

[1] No manure applied in 1907; cost of applying deducted.

Examination of Table XI shows that there was a small financial advantage due to the larger crop in favor of plots S, which represent the double handling system. Table XII shows a much larger difference. There are two reasons for this: first, the superiority of plots S during the period subsequent to that covered by annual applications of manure was much greater than during the period in which manure was applied yearly; and, second, this superiority, as already pointed out, has shown a tendency to increase with lapse of time.

While it has previously been referred to, it seems desirable again to call attention to the fact that spreading manure during the winter helps to relieve the pressure of work in the spring, and therefore possesses some advantage which cannot be shown in dollars and cents, and which of course varies with the weather and other conditions affecting the spring work.

TABLE XII. — *Calculated Results per Acre (1912–19).*

Crop.	Crop Values, Yearly Average. Difference in Favor of Spring (Plots S).	Number of Years.	Total Difference in Favor of Spring (Plots S).
Mixed grass and clover,	$2 10	4	$8 40
Soy beans (ensilage),	24	1	24
Soy beans,	10 04	1	10 04
Corn,	12 73	2	25 46
Total,	–	8	$44 14

Average for 1 year, $5.52.

FINAL CONCLUSIONS.

1. Had the experiment been brought to a conclusion in 1911, the last year of the period during which manure was applied annually, the statement would apparently have been justified that it made little difference in financial result which of the two plans of applying manure should be followed. This, however, would not have amounted to a demonstration that excess wastage had not occurred on plots N, for the reason that in spite of such wastage under the conditions which had existed throughout the experiment, the supply of plant food on plots N had probably been adequate to give yields nearly as large as all the conditions affecting the yields on plots S made possible.

2. That the manure on plots N had suffered quite serious losses has been made apparent by the relative yields as compared with plots S during the period 1912–19, in which no additional manure had been applied.

3. There must have been considerable excess wastage on plots N, even had the rate of application been smaller, although, of course, the financial loss would have been less.

4. The conclusion which appears to me to be fully justified by the results obtained to date (1919) is that the manure for the crop of the following season should be incorporated with the soil by the plow or harrow after the removal of the crop in the late fall, if practicable, rather than spread upon the surface to remain until spring.

5. There can be little doubt that the excess wastage on plots N would have been less on land which was more nearly level than that used in this experiment, but the land surface in Massachusetts and throughout a large part of the New England States is so broken that the proportion of land so level that there is no wash over the surface is comparatively small.

6. The earlier start and more rapid growth on plots S, especially during the later years of the experiment, are a decided advantage, and in many cases go far to insure a superior crop on account of the fact that the moisture supply in the early part of the season is more surely adequate to the needs of the crop, as a rule, than later.

Yet in one other way the earlier start and more rapid growth which doubtless occur in the root system as well as in the tops help to insure a good crop. I would refer also to the fact that crops which develop early and rapidly are far more likely to escape serious injury by insect enemies than those starting late or growing slowly, both because better able to resist attacks of such enemies, and because capable of quickly replacing tissues which are eaten or injured. In the case of some parasitic diseases, also, the plant making an early start and rapid growth is less likely to be seriously injured.

7. The earlier maturity of the crop on plots S constitutes an important advantage in favor of such practice as will prevent excessive loss of plant food. This of course is particularly true of crops thriving at relatively high temperatures, such, for example, as Indian corn and soy beans.

8. There can be no doubt that there is some wastage of nitrogen from winter-spread manure, and nitrogen is, as a rule, the most costly of the different plant-food elements; but reduction of the amount of wastage of nitrogen through the practice of piling and spreading the manure to be immediately incorporated with the soil in the spring is not the only nitrogen advantage connected with that practice. Particular attention has been called to the far greater proportion of clover on plots S than on plots N. Under these relative conditions it appears certain that a much greater amount of nitrogen must be taken from the air, and either made

a part of the harvested portion of the crop or left behind in the stubble and roots, on plots S than on plots N, thus reducing materially the necessity for application of nitrogen to crops in later years.

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BULLETIN No. 197.

DEPARTMENT OF CHEMISTRY.

THE NUTRITIVE VALUE OF CATTLE FEEDS.

1. VELVET BEAN FEED FOR FARM STOCK.

BY J. B. LINDSEY AND C. L. BEALS.

Summary of Results with Suggestions.

1. Velvet bean feed consists of the ground seeds and pods of the velvet bean, a leguminous plant grown quite largely in the southern States.

2. In chemical composition it resembles wheat bran, but contains rather more fiber, due to the presence of the bean pods.

3. As a result of digestion studies it was found to contain about 130 pounds, or 11.5 per cent, more digestible organic nutrients per ton than does wheat bran, and as a component of the dairy ration one would expect somewhat better results from its use.

4. Two feeding experiments were made with groups of six and four cows, in which the ration consisted of hay and a grain ration of 20 per cent cottonseed meal, 40 per cent corn feed meal, and 40 per cent velvet bean feed or wheat bran. The results show that the cows while receiving the velvet bean ration produced 2.7 and 9 per cent, with an average of 5 per cent, more milk than while on the wheat bran ration. It seems safe, therefore, to conclude that the velvet bean feed is somewhat superior to wheat bran for dairy purposes.

5. It may constitute as high as 40 per cent of a dairy ration, together with a like amount of corn or hominy meal or ground oats, and some 20 per cent of cottonseed or linseed meal, or other high-grade protein concentrate.

6. As a food for pigs a ration composed by weight of 50 parts corn feed meal, 40 parts velvet bean feed, and 10 parts digester tankage

or one composed of equal weights of corn feed meal and velvet bean feed, did not prove as satisfactory as one composed of 90 parts corn feed meal and 10 parts digester tankage; and so large an amount of the velvet bean feed is not recommended.

7. A ration composed by weight of 20 parts velvet bean feed, 20 parts high-grade peanut meal, 50 parts corn meal, and 10 parts alfalfa meal gave as satisfactory results as one composed of 80 parts corn meal and 10 parts each of digester tankage and alfalfa meal; and such combinations are to be recommended.

8. The addition of 10 per cent ground alfalfa to the grain ration for growing pigs in order to supply the necessary vitamines did not seem to exert any marked effect in promoting growth.

9. As a feed for horses, velvet bean feed, if sufficiently dry to prevent decomposition, may comprise some 20 per cent of the grain ration, mixed together with 30 per cent oats, 40 per cent cracked corn and 10 per cent wheat bran.

10. It is important that the velvet bean feed should be well dried before being shipped, otherwise more or less decomposition is likely to set in, and the feed proves unsatisfactory for use. The writer regards a satisfactory quality of velvet bean feed as a distinct addition to the protein concentrates at the disposal of northern feeders.

11. Velvet bean meal (beans minus the pods) would undoubtedly prove more satisfactory for pigs and horses.

A. What Velvet Bean Feed is.

The velvet bean, of which there are many varieties, is a tropical legume, and is grown largely in Florida, Alabama and Mississippi. It needs a long season for its maturity, and is grown rarely north of Savannah. It is a rank grower, its vines trailing on the ground to a length of from 15 to 75 feet; they are difficult to cure for hay and have been used largely for grazing. It is now becoming common to pick the best of the beans and use them without hulling for cattle, or hulled as a food for pigs. The former is termed velvet bean feed, and the latter velvet bean meal. Machinery has more recently been devised for drying and grinding the unhulled beans, and it is said that the industry is increasing rapidly. About a year since, more or less of the velvet bean feed was placed upon the Massachusetts market, but it did not seem to give the best of satisfaction, partly on account of the feeders' lack of familiarity with the product, and partly because of its being shipped in too moist a condition.

Considerable has already been published relative to the velvet bean, particularly concerning its habitat, growth, adaptability to various soil

and climatic conditions, as well as its suitability as a pasture crop, source of roughage, its value as silage and as a soil renovator.[1] Such information has a more particular value for parties residing in those States where the plant can be grown advantageously. Several experiments are also on record describing the feeding value of the ground bean and pods, and one experiment on its digestibility.

Inasmuch as the velvet bean feed (pods and beans) may become distributed in Massachusetts, experiments were undertaken at this station, particularly with reference to its digestibility and its suitability as a food for dairy stock, pigs and horses.

B. Composition of Velvet Bean Feed.

	Number of Analyses.	Water.	Ash.	Protein.	Fiber.	Extract.	Fat.
Velvet bean feed,	3	11.31	4.57	16.66	12.71	50.66	4.09
Wheat bran (for comparison),	116	10.00	6.20	16.10	10.00	53.30	4.40

The feed resembles wheat bran in chemical composition. It has slightly more protein, considerably more fiber, due to the presence of the bean pods, and somewhat less extract matter than wheat bran.

C. Digestibility of Velvet Bean Feed.

Two duplicate experiments were made with two different pairs of sheep. Two sheep were fed daily 550 grams of hay and 250 grams of the bean feed, and two other sheep 600 grams of hay and 200 grams of the feed. The results of the trials giving the amounts of the several constituents digested (digestion coefficients) are here stated, but the details of the experiments will be published elsewhere.

Results (Digestion Coefficients).

Sheep.	Dry Matter.	Ash.	Protein.	Fiber.	Extract Matter.	Fat.
XII,	82.06	41.48	76.64	81.07	89.71	86.69
XIII,	71.48	28.52	73.96	51.09	81.82	74.41
IX,	70.96	22.97	68.56	46.60	80.35	72.79
XI,	81.16	33.24	78.02	71.06	86.83	85.63
Average,	77	32	74	62	85	80
Average (Georgia station),[1]	79	58	74	64	77	86
Average (all results),	79	53	74	64	78	85
Wheat bran (for comparison),	66	–	77	39	71	63

[1] Farmers' Bulletins Nos. 300 and 962; Georgia Experiment Station Bulletin No. 129; Journal of Agricultural Research, Vol. XIII, No. 12, p. 611; Florida Experiment Station Bulletin No. 102.

Our own results with four sheep show some noticeable variations. Sheep XII and XI seem to have digested the feed better than the two other sheep. This variation is noticeable in each of the several ingredients. The average results agree quite closely with those secured by Ewing and Smith[1] with steers.

Applying the average coefficients to the chemical composition of the velvet bean feed we find 2,000 pounds of the material to contain the following: —

Digestible Organic Nutrients in 2,000 Pounds.

	Protein.	Fiber.	Extract Matter.	Fat.	Total.
Velvet bean feed, . . .	246.6	162.6	790.2	69.54	1,268.94
Wheat bran (for comparison), .	248.0	78.0	756.8	55.40	1,138.20

Velvet bean feed contains about the same amount of digestible protein as does wheat bran. Its content of digestible fiber, extract matter and fat is somewhat in excess of that contained in the bran, and on the basis of total digestible organic nutrients it is shown to have some 11.5 per cent more feeding value than the latter feed.

D. Velvet Bean Feed for Cows.

During the fall and winter of 1918–19 two feeding experiments with velvet bean feed were made with milch cows. In one case six and in the other four animals were used. They were divided into groups in each experiment, and were fed by the reversal method for periods of five weeks (besides preliminary periods) on a ration composed of hay for roughage and a grain mixture made up of 20 per cent cottonseed meal, 40 per cent corn feed meal (corn meal in second experiment), and 40 per cent of either velvet bean meal or wheat bran.

Before starting the experiment the cows were carefully chosen and paired off as well as possible in regard to age, breed, period of lactation, yield of milk, fat, etc.

The hay and grain rations were carefully calculated for each animal on the basis of milk and maintenance requirements according to the Haecker Standards.[2] The general care and management of the animals in no way differed from that always used in our feeding experiments, and require no discussion here. Hay and grain samples were taken at regular intervals, composited and analyzed. Milk samples were taken on the first, third and fifth weeks of each half of each experiment.

[1] P. V. Ewing and F. H. Smith in Journal of Agricultural Research, Vol. XIII, No. 12, p. 616. Results with five different steers in eighteen single trials.

[2] See Minn. Bul. No. 140, p. 56.

TABLE I. — *History of Cows.*

EXPERIMENT I.

Name.	Breed.	Age (Years).	Last Calf.	Served.	Beginning of Experiment.		
					Weight (Pounds).	Milk (Pounds).	Fat (Per Cent).
Samantha II,	Grade Holstein,	4	July 22, 1918,	– –	975	32	4.50
Peggy,	Grade Jersey,	8	Aug. 13, 1918,	– –	755	25	5.75
Red IV,	Grade Jersey,	5	Dec. 2, 1917,	June 2, 1918,	835	19	5.80
Samantha III,	Grade Holstein,	5	Aug. 26, 1918,	– –	1,140	30	4.60
Colantha III,	Grade Holstein,	4	Mar. 6, 1918,	June 12, 1918,	1,000	24	3.60
Fancy IV,	Grade Jersey,	4	July 22, 1918,	– –	700	21	4.63

EXPERIMENT II.

Name.	Breed.	Age (Years).	Last Calf.	Served.	Weight (Pounds).	Milk (Pounds).	Fat (Per Cent).
Samantha III,	Grade Holstein,	5	Aug. 26, 1918,	Dec. 5, 1918,	1,170	25	4.60
Fancy IV,	Grade Jersey,	4	July 22, 1918,	Oct. 30, 1918,	810	18	5.35
Colantha II,	Grade Holstein,	4	July 22, 1918,	Nov. 7, 1918,	1,050	30	4.25
Ida II,	Pure Jersey,	6	Oct. 27, 1918,	Dec. 9, 1918,	800	28	5.60

TABLE II. — *Total Amount and Average Daily Amount of Food consumed per Cow and per Ration (Pounds).*

EXPERIMENT I.

Velvet Bean Feed Ration.

Dates.	Cows.	Hay. Total.	Hay. Daily.	Velvet Bean Mixture. Total.	Velvet Bean Mixture. Daily.	Wheat Bran Mixture. Total.	Wheat Bran Mixture. Daily.
Oct. 1–Nov. 4, 1918,	Colantha II,	840.00	24.00	350.0	10.00	–	–
	Peggy,	697.75	19.94[1]	315.0	9.00	–	–
	Red IV,	665.00	19.00	245.0	7.00	–	–
Nov. 15–Dec. 19, 1918,	Samantha III,	840.00	24.00	315.0	9.00	–	–
	Colantha III,	735.00	21.00	280.0	8.00	–	–
	Fancy IV,	665.00	19.00	245.0	7.00	–	–
Totals,	. . . . .	4,442.75	–	1,750.0	–	–	–
Averages,	. . . . .	–	21.16	–	8.73	–	–

Wheat Bran Ration.

Dates.	Cows.	Hay. Total.	Hay. Daily.	Velvet Bean Mixture. Total.	Velvet Bean Mixture. Daily.	Wheat Bran Mixture. Total.	Wheat Bran Mixture. Daily.
Oct. 1–Nov. 4, 1918,	Samantha III,	840.00	24.00	–	–	315.0	9.00
	Colantha III,	735.00	21.00	–	–	280.0	8.00
	Fancy IV,	642.00	18.91[2]	–	–	245.0	7.00
Nov. 15–Dec. 19, 1918,	Colantha II,	840.00	24.00	–	–	350.0	10.00
	Peggy,	700.00	20.00	–	–	315.0	9.00
	Red IV,	665.00	19.00	–	–	245.0	7.00
Totals,	. . . . .	4,422.00	–	–	–	1,750.0	–
Averages,	. . . . .	–	21.15	–	–	–	8.73

EXPERIMENT II.

Velvet Bean Feed Ration.

Dates.	Cows.	Hay. Total.	Hay. Daily.	Velvet Bean Mixture. Total.	Velvet Bean Mixture. Daily.	Wheat Bran Mixture. Total.	Wheat Bran Mixture. Daily.
Dec. 30, 1918–Feb. 2, 1919.	Samantha III,	840.00	24.00	315.0	9.00	–	–
	Fancy IV,	665.00	19.00	245.0	7.00	–	–
Feb. 13–March 19, 1919,	Colantha II,	840.00	24.00	332.5	9.50	–	–
	Ida, II,	735.00	21.00	332.5	9.50	–	–
Totals,	. . . . .	3,080.00	–	1,225.0	–	–	–
Averages,	. . . . .	–	22.00	–	10.75	–	–

[1] Peggy left a total of 2.25 pounds of hay, or a daily average of .06 pound unconsumed.

[2] Fancy IV left a total of 3 pounds of hay, or a daily average of .09 pound unconsumed.

TABLE II. — *Total Amount and Average Daily Amount of Food consumed per Cow and per Ration (Pounds)* — Concluded.

EXPERIMENT II — *Con.*

Wheat Bran Ration.

Dates.	Cows.	Hay.		Velvet Bean Mixture.		Wheat Bran Mixture.	
		Total.	Daily.	Total.	Daily.	Total.	Daily.
Dec. 30, 1918–Feb. 2, 1919.	Colantha II,	840.00	24.00	–	–	332.5	9.50
	Ida II,	735.00	21.00	–	–	332.5	9.50
Feb. 13–March 19, 1919,	Samantha III,	840.00	24.00	–	–	315.0	9.00
	Fancy IV,	665.00	19.00	–	–	245.0	7.00
Totals,	. . . .	3,080.00	–	–	–	1,225.0	–
Averages,	. . . .	–	22.00	–	–	–	10.75

TABLE III. — *Analysis of Feeds (Per Cent).*

EXPERIMENT I.

Feed.	Average Moisture.[1]	Dry Matter.[1]	Dry Matter.				
			Ash.	Protein.	Fiber.	Extract Matter.	Fat.
Hay,	12.17 10.50	87.83 89.50	6.18	8.70	30.57	51.72	2.83
Velvet bean mixture,	11.31 9.72	88.69 90.28	4.08	20.56	11.42	56.12	7.82
Wheat bran mixture,	11.37 10.32	88.63 89.68	5.23	19.09	10.71	56.59	8.38

EXPERIMENT II.

Feed.	Average Moisture.[1]	Dry Matter.[1]	Ash.	Protein.	Fiber.	Extract Matter.	Fat.
Hay,	14.00 12.70	86.00 87.30	5.89	7.48	29.74	54.41	2.48
Velvet bean mixture,	11.19 10.24	88.81 89.76	4.00	19.22	9.22	63.20	4.36
Wheat bran mixture,	11.46 10.27	88.54 89.73	4.85	18.32	8.44	63.34	5.05

[1] The two figures in each case represent the average of three samples taken in each half of the trials.

TABLE IV. — *Total and Average Daily Amount of Dry Matter consumed in Each Ration.*

EXPERIMENT I.

Velvet Bean Ration.

Dates.	Hay.		Grain.		Grain.	
	Total.	Daily.	Total.	Daily.	Total.	Daily.
Oct. 1–Nov. 4, 1918, Nov. 15–Dec. 19, 1918,	3,940	18.76	1,566	7.46	–	–

Wheat Bran Ration.

Dates.	Hay.		Grain.		Grain.	
	Total.	Daily.	Total.	Daily.	Total.	Daily.
Oct. 1–Nov. 4, 1918, Nov. 15–Dec. 19, 1918,	3,938	18.75	–	–	1,561	7.42

EXPERIMENT II.

Velvet Bean Ration.

Dates.	Hay.		Grain.		Grain.	
	Total.	Daily.	Total.	Daily.	Total.	Daily.
Dec. 30, 1918–Feb. 2, 1919, Feb. 13–March 19, 1919,	2,669	19.06	1,894	7.81	–	–

Wheat Bran Ration.

Dates.	Hay.		Grain.		Grain.	
	Total.	Daily.	Total.	Daily.	Total.	Daily.
Dec. 30, 1918–Feb. 2, 1919, Feb. 13–March 19, 1919,	2,668	19.05	–	–	1,091	7.79

In each experiment the two rations contained the same amount of dry matter.

TABLE V. — *Average Dry and Digestible Nutrients in the Average Daily Ration (Pounds).*

EXPERIMENT I.

Ration.	Dry Matter.	Digestible Nutrients.					Nutritive Ratio.
		Protein.	Fiber.	Extract Matter.	Fat.	Total.[1]	
Velvet bean,	26.22	2.05	3.89	9.51	.77	16.22	1:7.4
Wheat bran,	26.18	1.97	3.74	9.24	.76	15.71	1:7.4

[1] Including fat multiplied by 2.2.

TABLE V. — *Average Dry and Digestible Nutrients in the Average Daily Ration (Pounds)* — Concluded.

EXPERIMENT II.

RATION.	Dry Matter.	DIGESTIBLE NUTRIENTS.					Nutritive Ratio.
		Protein.	Fiber.	Extract Matter.	Fat.	Total.	
Velvet bean,	26.87	2.24	3.87	11.87	.59	18.58	1:7.6
Wheat bran,	26.84	1.86	3.63	10.29	.53	16.31	1:8.1

The velvet bean ration contained rather more digestible matter than the wheat bran ration.

TABLE VI. — *Gain or Loss in Live Weight (Pounds) per Herd.*

RATION.	EXPERIMENT I.		EXPERIMENT II.		Total.
	Gain.	Loss.	Gain.	Loss.	
Velvet bean meal,	81	34	28	2	+73
Wheat bran,	135	0	32	8	+159

In the two experiments the cows when receiving the wheat bran ration seemed to gain a little more in weight than when receiving the velvet bean ration.

TABLE VII. — *Yield of Milk and Milk Ingredients.*

EXPERIMENT I.

Velvet Bean Ration.

DATES.	COWS.	Milk (Pounds).	SOLIDS.		FAT.	
			Per Cent.	Pounds.	Per Cent.	Pounds.
Oct. 1–Nov. 4, 1918,	Colantha II,	1,218.9	12.50	152.36	4.07	49.61
	Peggy,	885.8	14.89	131.90	6.30	55.81
	Red IV,	724.6	15.28	110.72	5.99	43.40
Nov. 15–Dec. 19, 1918,	Samantha III,	905.8	13.09	118.57	4.39	39.76
	Colantha III,	830.8	12.67	105.26	3.83	31.82
	Fancy IV,	672.0	13.82	92.87	5.21	35.01
Totals,	. . . . .	5,237.9	–	711.68	–	255.41
Averages,	. . . . .	–	13.59	–	4.88	–

TABLE VII. — *Yield of Milk and Milk Ingredients* — Concluded.

EXPERIMENT I — *Con.*

Wheat Bran Ration.

Dates.	Cows.	Milk (Pounds).	Solids.		Fat.	
			Per Cent.	Pounds.	Per Cent.	Pounds.
Oct. 1–Nov. 4, 1918	Samantha III	948.7	12.89	122.30	4.47	42.41
	Colantha III	796.0	12.47	99.26	3.90	31.04
	Fancy IV	739.7	13.80	102.08	5.10	37.72
Nov. 15–Dec. 19, 1918	Colantha II	1,163.0	12.69	147.58	4.01	46.64
	Peggy	831.8	15.54	129.26	6.44	53.57
	Red IV	620.5	16.14	100.15	6.47	40.15
Totals	. . . . .	5,099.7	–	700.63	–	251.53
Averages	. . . . .	–	13.74	–	4.93	–

EXPERIMENT II.

Velvet Bean Ration.

Dates.	Cows.	Milk (Pounds).	Solids Per Cent.	Solids Pounds.	Fat Per Cent.	Fat Pounds.
Dec. 30, 1918–Feb. 2, 1919	Samantha III	763.8	13.49	103.03	4.64	35.44
	Fancy IV	596.0	14.70	87.61	5.32	31.70
Feb. 13–March 19, 1919	Colantha II	1,260.0	13.40	168.84	4.51	56.82
	Ida II	827.6	14.81	122.86	5.81	48.19
Totals	. . . . .	3,447.4	–	482.34	–	172.15
Averages	. . . . .	–	13.99	–	4.99	–

Wheat Bran Ration.

Dates.	Cows.	Milk (Pounds).	Solids Per Cent.	Solids Pounds.	Fat Per Cent.	Fat Pounds.
Dec. 30, 1918–Feb. 2, 1919	Colantha II	995.8	13.03	129.75	4.33	43.31
	Ida II	862.9	14.74	127.19	5.85	50.47
Feb. 13–March 19, 1919	Samantha III	749.7	13.51	101.28	4.69	35.16
	Fancy IV	556.3	14.51	80.71	5.38	29.92
Totals	. . . . .	3,164.7	–	438.93	–	158.86
Averages	. . . . .	–	13.87	–	4.99	–

In the first experiment an increase in milk yield of 2.7 per cent was secured, and in the second experiment an increase of 9 per cent, both in favor of the velvet bean ration.

In both experiments the velvet bean ration yielded 8,685.3 pounds, and the wheat bran ration 8,264.4 pounds, of milk, an average increase of 5 per cent in favor of the velvet bean ration.

In case of the velvet bean ration 100 pounds of dry matter produced 130 pounds of milk, and in case of the wheat bran ration, 125 pounds.

It seems evident, therefore, on the basis of digestibility and feeding experiments with dairy cows, that the velvet bean feed is somewhat superior as a dairy feed to wheat bran.

E. Velvet Bean Feed for Pigs.

Observations with two lots of pigs were made, the first in 1918 and the second in 1919.

Experiment I. — August 12–November 20.

Six pigs having reached a weight of about 50 pounds each were divided into three lots of two each, and fed on the following rations: —

Lot I. — Mixture by weight of 80 parts corn feed meal, 10 parts alfalfa meal and 10 parts digester tankage.

Lot II. — Mixture by weight of 50 parts corn feed meal, 40 parts velvet bean feed and 10 parts alfalfa meal.

Lot III. — Mixture by weight of 50 parts corn feed meal and 50 parts velvet bean feed.

The mixture fed to Lot I was considered a standard or check ration. That fed to Lots II and III was intended to demonstrate the efficacy of velvet bean feed in place of the tankage. Alfalfa was used in one ration and omitted in one to note if it aided, because of its "vitamine" content, in promoting growth.

Method of Feeding. — Ten ounces of each mixture were added to each quart of water to satisfy appetite. The grain mixture was at first mixed with a little cold water to convert it into a paste, then very hot water added, and the slop fed milk warm. The pigs were fed three times daily.[1]

Housing. — Each lot of pigs was kept in an outdoor pen, protected from rain and sun, and given the run of a small yard.

Weighing. — Each pig was weighed weekly on Monday morning before feeding.

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[1] An ash mixture composed of 20 per cent salt, 40 per cent rock phosphate, 10 per cent ground limestone and 30 per cent wood ashes was kept constantly before the pigs in all of the experiments here described. The pigs also had access to charcoal.

Record of Feeds consumed and of Growth (Pounds).

Pigs.	Days.	Dry Matter in Feeds consumed.					Growth.				Dry Matter required to produce 100 Pounds Live Weight.
		Corn Feed Meal.	Alfalfa.	Tankage.	Velvet Bean Feed.	Total.	Weight at Beginning.	Weight at End.	Total Gain.	Daily Gain.	
1	101	344.2	41.7	36.5	–	422.4	52.5	180.5	128.0	1.27	330
2, ...	98[1]	320.2	38.8	34.3	–	393.4	57.5	182.5	125.0	1.27	315
3, ...	62	90.5	18.0	–	72.3	180.8	47.5	80.5	33.0	.53	548
4, ...	101	179.3	35.6	–	143.2	358.1	49.5	118.0	68.5	.68	523
5, ...	72	119.2	–	–	119.1	238.3	44.2	83.5	39.2	.55	600
6, ...	72	115.1	–	–	114.9	230.0	52.2	82.5	30.2	.42	795

[1] Sick for three days.

Pigs 1 and 2 had the advantage in that they were fed corn meal and skim milk when very young. Pigs 3, 4, 5 and 6 were fed different grain mixtures when too young and did not get as good a start. Pig 3 was badly out of condition and did not recuperate until August. Pigs 1 and 2 were normal in every way, and on the diet of corn feed meal and digester tankage for 101 days gained daily 1.27 pounds and produced 100 pounds of live weight for 322 pounds of dry matter fed. Pigs 3 and 4, on the diet of corn feed meal, velvet bean feed and alfalfa, and pigs 5 and 6, on a corn feed and velvet bean feed diet, gained noticeably less. All appeared healthy during the experiment, and ate well. Pigs 5 and 6 did not grow quite as well as pigs 3 and 4, and did not appear to be building out as good a framework. It seemed evident that the alfalfa was furnishing something in promoting early growth that was lacking in the diet fed pigs 5 and 6.

Although the experiment was not as satisfactory as one could wish, it at least indicated that so large an amount of velvet bean feed was not desirable in the daily diet, and that it was not a satisfactory substitute for digester tankage.

Experiment II. — June 9–November 1.

Six pigs, grade Chester White, weighing from 24 to 34 pounds each, were divided into lots of two each and fed on three different rations, two of which contained 20 per cent velvet bean feed in order to test its efficacy as a component of a grain mixture.

Lot I received by weight a mixture of 80 pounds of corn meal, 10 pounds of digester tankage and 10 pounds of ground alfalfa.

Lot II received by weight a mixture of 50 pounds of corn meal, 20 pounds of peanut meal, 20 pounds of velvet bean feed and 10 pounds of alfalfa meal. On July 8 the corn meal was increased to 60 pounds, the alfalfa eliminated and different kinds of green material fed from day to day.

Lot III received by weight a mixture of 60 pounds of corn meal, 20 pounds of peanut meal and 20 pounds of velvet bean feed.

Lot I, therefore, received the so-called standard or check ration, Lot II the velvet bean ration plus alfalfa meal or green material to assist in promoting growth, while in the case of Lot III this was omitted. From September 7 to September 20 coconut meal was substituted for the velvet bean feed because of lack of supply of the latter. The method of feeding, housing and weighing was the same as in Experiment I.

Record of Feeds consumed and of Growth (Pounds).

Pigs.	Days.	Dry Matter in Feeds consumed.						Growth.				Dry Matter required per 100 Pounds of Gain.
		Corn Meal.	Peanut Meal.	Velvet Bean Feed.	Digester Tankage.	Alfalfa Meal.	Total.	Weight at Beginning.	Weight at End.	Total Gain.	Daily Gain.	
1, . .	175	476.5	–	–	62.9	60.6	600.0	22	185	163	.93	368.1
2, . .	175	476.5	–	–	62.9	60.6	600.0	30	195	165	.94	365.0
3, . .	175	344.6	124.5	119.6[1]	–	4.4	593.1	27	162	135	.77	439.3
4, . .	175	344.6	124.5	119.6[1]	–	4.4	593.1	25	189	164	.94	361.6
5, . .	175	347.7	124.0	119.1[1]	–	–	590.8	34	185	151	.86	391.3
6, . .	175	347.7	124.0	119.1[1]	–	–	590.8	27	173	146	.83	404.6

[1] Includes 21.4 pounds of coconut meal.

Each of the pigs remained in a thrifty condition during the entire experiment, and from their looks one would not be able to say that one ration was proving more effective than another.

Lot I, receiving the corn and tankage mixture, made an average daily gain of .93 pound each, and required 366 pounds of dry matter to make 100 pounds of gain. An average for pigs of this size is .9 pound of gain daily, and a requirement of 377 pounds of dry matter per 100 pounds of gain.

Lot II, receiving the corn, velvet bean, peanut and ground alfalfa, made an average daily growth of .85 pound each, and required 400 pounds of dry matter for 100 pounds of gain. Pig 4 of this lot gained fully as well as either of the two pigs in Lot I, but for some reason, due perhaps to individuality, pig 3 made somewhat less daily gain.

Lot III, receiving substantially the same ration as Lot II, with the exception of the alfalfa, made an average daily gain of .85 pound each,

and required 398 pounds of dry matter per 100 pounds of gain. This latter lot did not do quite as well as Lots I and II, indicating possibly that the lack of alfalfa may have slightly checked growth, but the difference was so slight as not to warrant one in drawing any positive conclusions. The combination of corn meal, alfalfa, velvet bean feed and peanut meal gave as satisfactory results as corn meal and tankage, and indicates that some 20 per cent of velvet bean feed, when properly combined, can be used as a component of the ration for growing pigs.

A ration containing 40 to 50 per cent of velvet bean feed together with corn meal (Experiment I) proved unsatisfactory and its use in such amounts is not recommended.

F. Velvet Bean Feed for Horses.

Velvet bean feed of good quality was fed to two farm horses for a period of three months, comprising some 18 per cent of the daily grain ration, which was as follows: —

Grain Mixture.

	Pounds.
Oats,	100
Corn,	140
Wheat bran,	40
Velvet bean feed,	60

The horses received from 17 to 20 pounds daily of the mixture, did regular farm work and maintained their live weight. Velvet bean feed, if dry and free from mold, can be used in the amounts indicated with safety.[1]

Velvet bean meal (beans minus pods) would undoubtedly prove better suited as a feed for pigs and horses.

[1] For a fuller report, see Bulletin No. 188, pp. 259-262.

BULLETIN No. 198.

DEPARTMENT OF CHEMISTRY.

STUDIES OF CRANBERRIES DURING STORAGE.

CHEMICAL STUDIES.

BY F. W. MORSE AND C. P. JONES.

Chemical Changes in Cranberries in Storage.

For several years the Massachusetts Agricultural Experiment Station has been studying problems connected with the storage and shipment of cranberries, during the course of which chemical data have been gathered that are here arranged to show the composition of a few well-known varieties of cranberries and some of the changes which take place in their composition while they are held in storage.

The essential qualities of a fruit that is to be used for cooking or dessert are juiciness and flavor. With our present knowledge of analytical chemistry such qualities can be measured only in terms of water, sugar and acid, since as yet there are no sure methods for determining the characteristic fruit flavors or esters. Therefore determinations of water, total sugar and total acid were made in all our samples of cranberries, while the proximate analysis of the food constituents was executed on some of them.

The analyses of varieties have been selected as far as possible to show them at their best. The Early Black and the Howes varieties were sampled in October from lots stored at natural temperatures, while the McFarlin and Centennial varieties were sampled in November from lots in cold storage. Early Black is the earliest variety shipped from the Cape Cod district. It is of good quality, but is not a good keeper. Howes is a later variety and forms the main crop on many of the bogs. It is a good keeper, but is not equal to some other varieties in quality. The other two varieties are rated among growers as "fancy" kinds, and are grown in limited quantities. The McFarlin is an excellent variety in quality, but not as good a keeper as Howes. The Centennial is a very large berry, attractive on account of its size, of good flavor, but not as juicy as the others. Cranberries, however, are not sold under their variety names, like apples, but

usually bear brands, originated by the sales organizations, which are unrelated to the varieties.

Two lots of Wisconsin cranberries were sent to the laboratory from that State by Dr. N. E. Stevens. One variety was the well-known McFarlin, and the other was a fancy western variety, of attractive size and color, called Searl's Jumbo. The sugar content was a bit inferior to our Cape varieties in both samples, but the fruit was sent by parcel post in tight packages, and was probably in warm mail cars and rooms while in transit. Such conditions induce a somewhat rapid change in sugar content, as shown by our storage experiments.

The composition of the varieties is shown in the following table: —

TABLE I. — *Composition of Varieties of Cranberries in October.*

VARIETY.	Water.	Total Sugar.	Total Acid.
Early Black,	87.86	4.12	2.45
Howes (two lots),	87.44	3.95	2.31
McFarlin,	88.74	4.08	2.12
Centennial,	87.16	5.59	2.05
Searl's Jumbo (Wisconsin),	89.25	3.48	2.61
McFarlin (Wisconsin),	88.47	3.75	2.49

Proximate Food Constituents.

VARIETY.	Dry Matter.	Ash.	Protein.	Fiber.	Ether Extract.	Nitrogen-free Matter.
Howes,	12.23	.15	.35	1.51	.97	9.25
McFarlin,	11.26	.16	.35	1.18	.57	9.00
Centennial,	12.84	.17	.28	1.15	.51	10.73

It has been noted that the cranberries undergo some change in composition during the storage period, although they remain firm and sound, with no evidence of decay. The change is most pronounced when the fruit is held at the higher temperatures of storage in a warm room, and is barely noticeable at cold-storage temperatures just above the freezing point.

In the fall of 1917 changes in the fruit during storage were studied by the analysis of berries kept in the storehouse at the cranberry bog. Fruit of the Howes variety was sent to the laboratory at monthly intervals directly from the storehouse, by express or parcel post, in small, ventilated crates holding about 8 quarts. The first lot was shipped in October, soon after the fruit had been stored, and the final lot in February. No attempt

was made to ascertain the shrinkage in weight of the fruit during storage, since berries were all the time decaying, and no lot of selected fruit would fail to have more or less rotten berries in a week's time, and such berries lose water more rapidly than sound ones. To have correctly determined losses in weight of sound fruit over a period of months would have required the individual weights of a large number of berries, so that decayed berries could be rejected as they developed, and only sound berries weighed individually at the end of a given period. The chemical analyses included determinations of water, total sugar and total acid.

In 1918 the work was repeated in a similar manner with samples from the bog storehouse. In addition, several lots of cranberries were placed in the cold-storage rooms of the Horticultural Department about the middle of October, and samples were analyzed at intervals to compare their rate of change with the changes in the cranberries kept at the bog. The cold-storage house was built especially for fruit storage, and the fruit in it is held almost constantly just above 0° C. (32° F.).

The composition of the berries under different conditions of storage is shown in Table II.

TABLE II. — *Composition of Cranberries in Storage, 1917–19.*

	Dry Matter.	Total Sugar.	Total Acid.
Howes Variety.			
Storehouse: —			
Oct. 5, 1917,	12.89	3.97	2.28
Oct. 17, 1917,	–	3.85	–
Oct. 31, 1917,	11.81	–	–
Dec. 3, 1917,	11.58	3.27	2.32
Jan. 3, 1918,	11.76	3.47	2.37
Jan. 28, 1918,	11.78	3.58	2.26
Oct. 16, 1918,	12.23	3.93	2.34
Nov. 21, 1918,	12.06	4.19	2.15
Dec. 19, 1918,	12.10	4.18	2.01
Cold storage: —			
December, 1918,	12.14	4.04	1.96
January, 1919,	12.50	3.89	2.14
February, 1919,	12.54	3.72	2.17
McFarlin Variety.			
Cold storage: —			
November, 1918,	11.26	4.08	2.12
January, 1919,	11.59	4.09	2.12
Centennial Variety.			
Cold storage: —			
November, 1918,	12.84	5.59	2.05
January, 1919,	13.11	5.54	2.08

The samples for analysis invariably consisted of the firm, hard berries, with no evidence of decay. Some of the analytical results make it appear possible that selected lots of berries like these do not necessarily show progressive changes in composition for the average fruit of the early part of the season, but that the later berries are resistant to decay by less active cell organization and lower rate of metabolism.

In 1917 the Early Black cranberries picked from the little bogs at the Experiment Station were sampled and analyzed on September 25, soon after picking. The remainder was divided into two portions, one of which was placed in a refrigerator, and the other was left on a shelf in the basement at a temperature a little above the outside air on the average. These lots were sampled and analyzed four weeks later. The two lots were then allowed to stand until January, 1918, when the refrigerator lot was freed from all soft berries and sampled; while the lot from the basement was divided into two portions, one consisting of firm, sound berries, and the other, while free from rotten fruit, consisting of berries that were soft and rubber-like in physical appearance. Analyses of these lots of berries showed some striking differences.

TABLE III. — *Composition of Early Black Cranberries under Different Conditions of Storage.*

	Total Solids.	Total Sugar.	Total Acid.
Recently picked, September 25,	12.14	4.12	2.45
Two weeks later, October 8,	-	4.48	2.36
From refrigerator, October 23,	-	4.17	2.49
From basement, October 23,	-	3.99	2.43
From refrigerator, January,	11.01	3.51	2.35
From basement, January, firm,	10.59	2.62	2.55
From basement, January, soft,	11.76	2.75	2.63

The character of the package in which cranberries are stored and shipped has been closely related to changes in the properties of the fruit. In the course of storage investigations, made to determine the causes of cranberry spoilage after harvesting, Shear and Stevens observed a considerable number of berries that were soft, but which contained no organisms of decay.[1] Since the more thoroughly oxygen was excluded from the fruit the larger the quantity of softened berries, the trouble appeared to be caused by the lack of ventilation, and the berries were regarded as asphyxiated.

In December, 1917, Dr. Stevens brought to the laboratory directly

[1] Proc. Amer. Cranberry Growers' Assoc. 48 (1917), pp. 6-9. Mass. Agr. Expt. Sta. Ann. Rept. 30 (1918), pp. 235-239.

from Washington several lots of Howes berries that had been stored in small cans from which the air had been displaced by carbon dioxide gas. The fruit had been held in these cans for two months at different temperatures, viz., 0°, 5°, 15° and 20° C. (32°, 41°, 59° and 68° F.). Some berries at each temperature still remained firm and sound, although at 20° C. there were not enough for a satisfactory analysis. The softened berries had been attacked by the end rot fungus in most cases, but from the lot held at 0° C. enough typically asphyxiated berries were secured for chemical examination. The analyses of the sound berries showed a slightly lower sugar content at the higher temperatures, with practically no changes in water and acidity. The asphyxiated berries, although kept at the lowest temperature, contained much less sugar than any of the sound berries, indicating a much more destructive action on the fruit sugar when oxygen was lacking.

TABLE IV. — *Howes Cranberries stored at Fixed Temperatures.*

	Water.	Total Sugar.	Total Acid.
Sound berries at 0° C.,	88.30	3.56	2.25
Sound berries at 5° C.,	88.29	3.51	2.29
Sound berries at 15° C.,	88.45	3.37	2.24
Asphyxiated berries at 0° C.,	–	2.38	2.40

A small sample of asphyxiated berries with but little evidence of rot about them was selected from the combined lots stored at 15° and 20° C. The determination of sugar in this sample showed but 2.04 per cent.

It is a common practice in the household to preserve cranberries by sealing them in jars filled with water. One experiment was tried to determine the effect of such treatment on the composition of the fruit.

Two fruit jars were filled with cranberries from the lot of Howes received from the Experiment Station bog in October. Distilled water was added to the jars until they were brimful, when the covers were put on and clamped as in canning fruit. The jars were set away in a cool room and allowed to remain until February. When the jars were opened the water was found to contain carbon dioxide which escaped in bubbles as soon as the pressure on the covers was released. The fruit showed no signs of rot, but every berry was softened and felt like rubber. The water contained acid, sugar and coloring matter that had diffused from the fruit. The berries contained 10.36 per cent dry matter, 2.85 per cent sugar and 1.87 per cent acid, — quantities considerably less than in the same kind of berries stored in a cool room. While decay had been prevented, the absence of air had produced results similar to the asphyxiated fruit previously described.

The results of these different experiments show a steady loss of sugar

by cranberries during storage, and this loss is greater at the higher temperatures, while the destruction is further accelerated by a lack of air. The total acidity changes were very little, hence on account of its high proportion in cranberries they do not lose flavor on long keeping as noticeably as some other fruits.

Respiration of Cranberries.

The percentage changes in the composition of fruits produced by different storage temperatures throw little light on the real rate of change at a given temperature. A simple method of estimating the rate of chemical change in fruit at any given temperature is to determine the amount of carbon dioxide exhaled by a definite weight of the fruit in an hour. The carbon dioxide is produced by respiration of the fruit, just as it is produced in animals by the same action. The oxygen of the air penetrates the cells [1] of the fruit and unites with some of the matter in the cells, apparently the sugar, and forms carbon dioxide and water which are exhaled. There is no appearance of rhythmical action, as in the breathing of animals, but the exhalation of the carbon dioxide and water can be readily determined by chemical means.

Respiration experiments with several kinds of fruits [2] have been reported, and it has been shown that respiration varies noticeably with changes in the temperature of the fruit.

Respiration experiments with cranberries were carried out during two seasons, 1917–18 and 1918–19. One kilogram of cranberries was used in nearly every case, and whenever possible for convenience in calculation. The berries were carefully hand-sorted before weighing the desired quantity, in order to avoid any berries which had begun to rot. It was impracticable to hold the cranberries closely to a given degree of temperature during a run, and it was found necessary to maintain them for several hours before a run as closely as possible to the temperature desired to be tried in the respiration chamber, because the internal temperature of the berries was slow to adjust itself to that of the chamber if they were far apart, and the exhalation of carbon dioxide might be too high or too low accordingly. By close attention to details and to the thermometer, the range of temperature during any one run was kept within one or two degrees. Several different temperatures were tried, from about 2° to 25° C. (35° to 77° F.). The lowest temperatures were obtained by setting the respiration chamber inside a small tank which could be packed with snow. Temperatures around 10° C. were obtained at times by surround-

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[1] The authors' attention has been called by Dr. Stevens to a little-known paper by Winton (Conn. Agr. Expt. Sta. Ann. Rept. 1902, p. 288), in which is noted the absence of stomata in the epidermis of the cranberry. Bergman, while studying the cranberry, rediscovered this fact, and a paper by him is in press in the bulletin of the Torrey Botanical Club.

[2] Morse, Jour. Am. Chem. Soc. 30 (1908), pp. 876–881; N. H. Agr. Expt. Sta. Bul. No. 135 (1908). Gore, U. S. Dept. Agr., Bur. of Chem. Bul. No. 142 (1911). Hill, Cornell Univ. Expt. Sta. Bul. No. 330 (1913).

ing the chamber with running water, and at others by carrying on the runs in a cool basement. A warm room, such as the laboratory, served for the higher temperatures.

The results given in the following table are selected from a large number of trials, and are those in which the fruit, before and during the experiment, underwent a narrow range of temperature.

TABLE V. — *Exhalation of Carbon Dioxide by One Kilogram of Cranberries in One Hour.*

Surroundings.	Temperature (Degrees C.).	Determinations.	Milligrams CO_2.
Packed snow,	1–3	5	3.7
Cold room,	6–7	3	7.0
Running water,	9–11	5	7.7
Running water,	11–13	6	9.7
Warm room,	17–20	4	15.4
Warm room,	19–21	3	16.9
Warm room,	22–25	2	18.7

It will be readily seen that the amount of carbon dioxide exhaled doubled with a rise of 10° C. in temperature, which is in accord with the general law for the acceleration of chemical activity.

The temperatures of practical importance are those of cold storage, cool storehouses and warm rooms, or temperatures of 1° to 3°, 9° to 11°, and 20° to 25° C. Cranberries in a warm room are respiring from four to five times as fast as fruit in cold storage, while the fruit in a cool storehouse is twice as active as in cold storage.

These respiration experiments serve to confirm and explain the disappearance of sugar in the cranberries during storage and the increase in such loss at higher temperatures. The rate of respiration helps to explain the asphyxiation of the cranberry described by Shear and Stevens.

By packing cranberries in glass jars and then measuring the amount of water required to fill the air spaces remaining, it was found that in tightly packed barrels of the fruit there could not be more than 75 cubic inches of air for each quart of berries. Since only one-fifth of the air consists of oxygen, it was calculated that in about thirty-six hours, at the cool temperature of 10° C. (50° F.), the cranberries would exhaust the oxygen and replace it with exhaled carbon dioxide. Therefore, if there were no exchange of air between the outside and the inside of a barrel of cranberries, it would be only a few hours before asphyxiation would begin. Fruit, however, does not die as quickly as animals in the absence of air. There is a form of respiration called intracellular respiration, by which sugars decompose to alcohol and carbon dioxide. This is always the result with

yeast in alcoholic fermentation. Similar results are found with fruits. Carbon dioxide has been found to be exhaled by fruit in nitrogen gas[1] at about the same rate as by fruit in air. The destruction of sugar under such conditions is theoretically twelve times as great as when oxygen is available.[2]

In our work with cranberries the rate of destruction of sugar in tight packages was shown to be much greater than in well-ventilated ones. At the same time, it was noted that many berrics were very resistant to the conditions, and showed little or no signs of asphyxiation. It is possible that such berries have a lower rate of chemical activity, because, as Gore[3] has shown, the varieties of fruit which may be kept a long time, like oranges and lemons, have a much lower rate of respiration than fruits like grapes and strawberries, which spoil quickly.

A third study of the rate of respiration was made in January and February, 1920, with the object of learning whether the different varieties varied in their activity at a given temperature. It was necessary to have as constant a temperature as could be maintained with the means at our disposal. Through the co-operation of the Pomology Department we were enabled to carry on the work in one of the cold-storage rooms in which the temperature changes were comparatively small and slow, and the different varieties were studied under closely comparable conditions.

The cranberries were received from the Experiment Station bog in November, 1919, and had been held in a room with apples at a temperature of 32° to 33° F., until the respiration experiment was reached in January. They were then transferred to the room in which the respiration apparatus was set up, so that they would be at the temperature of the trial at all times. Four varieties of cranberries were used. The Howes variety was studied, with especial attention to possible changes in the rate of respiration as the storage period advanced, and the other varieties were compared with the Howes and with each other, as there was opportunity. A fresh lot of berries was taken from the crate and carefully hand-sorted for each day's trial in order to exclude any unsound fruit. The experiment was conducted as in all the previous cases.

[1] Hill, Cornell Univ. Agr. Expt. Sta. Bul. No. 330.

[2] Palladin, Plant Physiology, tr. by Livingston, Blakiston, 1918, p. 180.

[3] Gore, U. S. Dept. of Agr., Bur. of Chem. Bul. No. 142.

TABLE VI. — *Exhalation of Carbon Dioxide by Varieties of Cranberries.*

Date of Experiment.	Temperature of Berries (Degree C.)	Milligrams CO_2 per Kilo and Hour.			
		Early Black.	McFarlin.	Centennial.	Howes.
January 19,	1.2	3.9	–	–	–
January 20,	.6	–	4.8	–	–
January 21,	.4	–	–	5.6	–
January 22,	1.9	–	–	–	4.8
January 27,	2.1	2.6	–	–	–
January 28,	1.7	–	4.9	–	–
January 29,	2.0	–	–	4.7	–
January 30,	1.7	–	–	–	4.2
February 3,	1.5	3.7	–	–	–
February 4,	2.3	–	4.9	–	–
February 5,	1.8	–	–	5.0	–
February 6,	3.0	–	–	–	4.7
February 11,	3.4	–	5.8	–	–
February 12,	3.2	–	–	5.7	–
February 13,	3.0	–	–	–	4.9
February 16,	3.0	–	5.0	–	–
February 17,	2.3	–	–	–	4.2
February 25,	3.9	–	–	–	4.3
February 26,	3.6	–	–	4.7	–

The table shows a pronounced difference between the Early Black and the Centennial in the rate of respiration, but very little, if any, between the Howes, McFarlin and Centennial. There is a slight indication of a decrease in activity by the Howes as the storage period lengthened. Theoretically this decrease should occur, but on account of other variables it is not readily demonstrated. Since Early Black had passed its prime for quality at the date of the experiment, it is possible that its lower activity was due to a loss of vitality.

Keeping Qualities of Cranberries in Cold Storage.

Some simple tests of the keeping qualities of cranberries in cold storage have been made in connection with the chemical studies, since it was necessary to have a considerable quantity of fruit on hand to insure plenty of sound berries throughout the season. When the cranberries were re-

ceived from the substation at East Wareham, they were placed in the cold-storage house at the College under the same conditions that were maintained for apples. The cold-storage house is a modern building in which the temperature can be kept practically constant week in and week out, which for apples is just above the freezing point, or between 32° and 33° F. The cranberries were stored in ventilated crates holding a half barrel each. There was some evidence that the berries in the center of a crate decayed a little more than those near the surface, but these crates are as small as will be economical for storage and transportation.

When a sample of fruit was required for the chemical studies, a quantity of berries was removed from a crate, carefully sorted by hand, and the different portions weighed. Especial care was taken to have only perfect fruit for the chemical experiments; therefore some berries were rejected which would have been included among sound fruit by the ordinary methods of sorting for the trade. The shrinkage was consequently somewhat greater than would occur in practical storage. The relative keeping qualities of the different varieties should hold, however.

In the fall of 1918 the cranberries were received at the Experiment Station on September 26, kept in a cool room until October 3, and then placed in cold storage with apples. The first lots were removed on November 20, and others at intervals until February 18. The percentages of perfect fruit are given in Table VII.

For the season of 1919 the cranberries were received in November and placed at once in the storage room with apples. Previously they had lain in the store room at the bog in East Wareham at natural temperatures. The first lot was taken from cold storage on Jan. 13, 1920, at which time the crates were removed to a room without ice for the subsequent respiration experiments, but at no time was the temperature observed to go above 37° or 38° F. in this room, which was insulated from outside temperature changes. In this series of tests one variety was used at a time, but all were examined within a week, so in the table below the dates are given for weeks instead of definite days in which berries were sorted.

TABLE VII. — *Keeping Quality of Cranberries.* (*Per Cent Sound Fruit.*)

Date.	Early Black.	Centennial.	McFarlin.	Howes.
1918-19.				
November 20,	-	86.5	74.5	-
December 16,	38.3	-	-	-
January 14,	-	68.0	55.0	78.5
February 18,	-	-	-	75.0
1919-20.				
January 13-20,	46.3	60.6	63.7	64.9
January 27-February 4,	42.5	51.8	53.2	58.5
February 12-17,	-	44.9	52.0	62.1

It is evident from the results that Howes was the only variety that would keep well enough to make storage possible until midwinter in order to extend the marketing season. The other varieties, however, are better in eating qualities, and might be used for the manufacture of jam and jelly in seasons of abundant crops.

Cranberry Vinegar.

In September, 1918, an early frost injured many acres of cranberries, and the question was asked of the Experiment Station whether it was possible to utilize the frosted fruit as a source of vinegar. Consequently a lot of the frozen berries was secured by Dr. Franklin for the preparation of some juice for a fermentation experiment. It was found impossible with a machine to separate rotten berries from the fruit softened by the frost, and the cranberries were used without sorting.

The juice was pressed from the berries early in October by means of a hand cider mill. A lot of juice from sound fruit was prepared at the same date for comparison with regard to quality. Both lots of juice possessed a very disagreeable, bitter, acid taste. They remained under favorable conditions for fermentation until December 19, when they were received at the chemical laboratory for analysis.

Careful tests were made for alcohol in the juice by repeated distillation to concentrate it, and the application of the iodoform reaction to the final distillates. Neither juice showed more than a trace of alcohol in the final reaction, so that little fermentation had occurred.

Total acid and total sugar were determined in the different juices by the methods employed for the cranberry analyses. The results were found to be 2.3 per cent acid and .8 per cent of sugar in the juice from frozen berries, and 2.9 per cent acid and 2.6 per cent sugar in the juice from sound berries. Had the sugar all fermented to acid there would not have been sufficient strength to make a legal vinegar, while the taste would condemn its use in any case. Freezing resulted in a marked lowering of sugar in the fruit. The failure to ferment freely is probably due to the benzoic acid, which is a natural constituent of the cranberry. It does not appear practicable to utilize waste cranberries for vinegar.

Summary.

This bulletin reports the results of a chemical investigation made on the changes taking place in stored cranberries.

After the cranberries are picked from the vines they still remain living organisms. Storage conditions should be such that the life of these organisms may be prolonged instead of death being hastened.

Cranberries lose some of their sugar during storage. This loss is due to the respiration of the living berries, which respiration is less rapid at low temperatures than at high temperatures. For this reason the warmer the berries are kept the greater the loss of sugar during storage.

In order to have complete respiration, berries require a constant supply of oxygen during storage. Without this they become asphyxiated and die prematurely.

Good storage must include control of both ventilation and temperature.

Methods.

For the Determination of Chemical Composition.

In drying the cranberries for the determination of water it was necessary either to puncture the skin of the berry in numerous places with a pin, or to cut it into quarters with a knife. Fifty grams of cranberries were punctured or cut in pieces and spread in a shallow glass dish which was placed in a drying oven at a temperature between 50° and 60° C., where it remained until the fruit was brittle enough to be easily pulverized. The dish and contents were then cooled in the open air and the weight of dried material ascertained, after which it was pulverized and stored in a tightly corked bottle. Weighed charges of the air-dry material were subsequently used for moisture determinations, and the total water content of the cranberries calculated.

For the determination of sugar and acid, 50 grams of cranberries were mashed, a few at a time, in a porcelain mortar and washed with water into a 500 cubic centimeter volumetric flask by the aid of a wash bottle, short-stemmed funnel and long glass rod. The flask and contents, which amounted to 300 cubic centimeters, were set on a boiling water bath and allowed to stand about one hour. The flask was frequently shaken, and the pulp and water finally made a fairly homogeneous mass through which the sugar and acid were diffused. The liquid was cooled to room temperature and made up to 500 cubic centimeters. The flask was shaken and the contents then poured on a fluted filter large enough to hold the whole. The funnel was covered and a flask used to catch the filtrate so that evaporation would be reduced as much as possible. Aliquots of 100 cubic centimeters were used for sugar determinations, which were limited to the total sugar after inversion. Clarification was accomplished with Horne's dry lead subacetate, and the soluble lead in the cleared solution was removed by dry sodium carbonate.

Total acidity was determined in aliquots of 25 cubic centimeters of the cranberry solution, which were diluted with several volumes of water and titrated with tenth-normal sodium hydrate, using phenolphthalein as the indicator. The pink color of the cranberry solution seemed at first to make the use of an indicator almost impracticable, but the cranberry pigment proved to be a crude indicator itself. As the alkali was added the pigment changed from pink to blue, and subsequently faded to a pale green as more alkali was introduced. The end point was clearly marked by the appearance of a dark purple tint when the turning point of phenolphthalein was reached. The total acid was calculated as citric acid, though benzoic acid[1] and malic acid[2] have been shown to occur in small quantities in the cranberry.

The proximate food constituents — ash, protein, fiber, ether extract and nitrogen-free matter — were determined in the dried material by the standard methods.

Ether extract from the cranberry is a mixture of true fat from the seeds, wax from the skin and more or less of the fruit acids, — citric, malic and benzoic, — all of which are soluble in ether, the last most easily. In some of the samples the ether extract was warmed with the addition of water, and its acidity determined, but as it could be only an approximate correction it was thought best to leave the total ether extract uncorrected for acids present in it.

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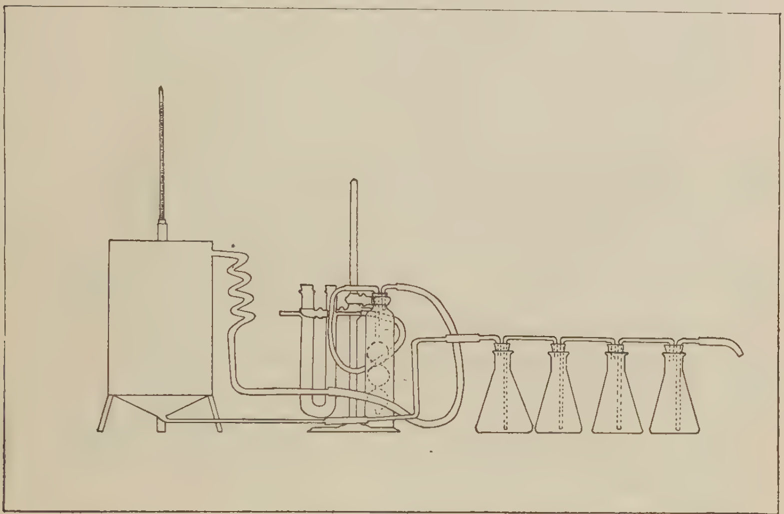
[1] Mason, Jour. Am. Chem. Soc. 27 (1905), p. 613.

[2] Bigelow and Dunbar, Jour. Indus. and Engin. Chem. 9 (1917), p. 762.

For the Determination of Rate of Respiration.

The apparatus consisted of a respiration chamber into which air freed from any carbon dioxide could be drawn, and from which the air could be conducted through a liquid which would absorb all of the exhaled carbon dioxide carried along in the current.



Respiration Apparatus.

The respiration chamber was of tin and would hold about 3 quarts. It was open at the top and was closed by a disk of tin which rested on a narrow shelf extending around the inner wall a half inch below the top. The bottom was funnel-shaped with the outlet for the exhaled gas projecting from the lowest part, so that the carbon dioxide, which is heavier than air, could be completely removed. The inlet for purified air was just below the cover of the chamber. Inside the chamber was a loose, false bottom, perforated with numerous small holes, which prevented the cranberries from settling down and blocking the outlet. The false bottom supported a tube three-eighths of an inch in diameter which rose through the center of the chamber and projected an inch above the cover. This tube was also perforated with holes in the portion below the cover, and served to hold a thermometer and to permit free circulation of air through the mass of berries. The cover was sealed in place by means of putty around the inner walls and the central tube, and a cork, through which passed the thermometer, stopped the tube. The outer end of the inlet tube was joined to the purification apparatus which consisted of a U tube containing dry soda lime, and a bulb tube containing a strong solution of sodium hydroxide. The air bubbling through the solution was moistened before entering the chamber, while the bubbles marked the movement of the air and served to indicate leaking joints. The outlet tube connected with a train of four small flasks, each of which contained a measured amount of standard solution of barium hydroxide, by which all the carbon dioxide was absorbed and precipitated as barium carbonate. A current of air was drawn through the entire apparatus by an aspirator which was regulated so that the air in the respiration chamber would be renewed about once in every hour. As a rule, each experiment was run six hours. Some were conducted for longer periods, but six hours was most convenient and satisfactory.

FUNGI STUDIES.

BY BERT A. RUDOLPH AND H. J. FRANKLIN.

Relative Prevalence of Fungi causing Rots of Cranberries at Different Periods during the Storage Season.[1]

Decay of cranberries in storage has been reported to be caused by more than ten species of fungi. The study of these storage rots and their control is complicated by the fact that the fungi causing them vary greatly in their relative abundance during different seasons. Moreover, berries from the various bogs within a given region are often found to be affected with different fungi, and there is apparently some difference in varieties on the same bog. Finally, in any given lot of berries there seems to be a more or less definite succession among the fungi causing decay during the storage period. The present paper deals especially with the last-mentioned point.

The plan of work in 1916–17 was as follows. Twelve storage boxes (1 bushel capacity) were filled with Early Black cranberries from a uniform area on the station bog at East Wareham, Mass., and placed in storage in the basement of the screen house, together with a similar lot of Howes. Beginning September 27 quart samples of sound berries were selected weekly from each variety and stored for two weeks in quart cans (which were closed but not sealed) at room temperature, after which they were sorted, and the berries which had rotted during the two weeks were sent to Washington. Here at least 60 cultures were made[2] from each lot of rotten berries by sterilizing the outside of the berry by immersing for five minutes in mercuric chloride solution (1–1000) and transferring a portion of the pulp to culture media by means of sterile forceps. In case fungi developed which did not fruit readily on the culture medium first used, subcultures were made on oat, beef, glycerine and corn-meal agar.

In the work of the season of 1917–18 the method was modified in several particulars. Closed cans were abandoned in favor of open boxes for the storage of the selected sound berries, the interval between tests was four

[1] The work summarized in this paper forms a part of the study of the spoilage of cranberries after harvest, which is being carried on jointly by the Massachusetts Agricultural Experiment Station and the United States Department of Agriculture. For further information on this general subject see Mass. Agr. Exp. Sta. Buls. Nos. 168 and 180, and U. S. Dept. Agr. Bul. No. 714.

[2] The fungi were all cultured and identified by Rudolph, whose enlistment in the navy late in 1917 prevented the completion of the work planned for that season. Mr. Rudolph was at that time scientific assistant, fruit disease investigations, Bureau of Plant Industry.

weeks, and the sound berries selected for each keeping test were divided into two lots, one of which was kept at room temperature and the other at a constant temperature of 20° C. The only considerable difference in the results due to the difference in method is that the number of sterile (*i.e.*, apparently smothered) berries was smaller during the season of 1917–18. In this respect the results of the second year are more reliable. Storing the berries at a constant temperature (20° C.) apparently changed the results little, which indicates that, in so far as concerns the kinds and abundance of the fungi which developed, those obtained in 1916 with the berries stored at room temperature are satisfactory.

More than a dozen species of fungi occurred in the cultures made during the first season. Of these, seven are known to be more or less important causes of decay of cranberries in storage, namely, *Guignardia vaccinii* Shear (early rot); *Glomerella cingulata vaccinii* Shear (bitter rot); *Fusicoccum putrefaciens* Shear (end rot); *Ceuthospora lunata* Shear (black rot); *Sporonema oxycocci* Shear (ripe rot); *Penicillium* spp. (soft rot); and *Phomopsis* sp. Table I shows the relative prevalence of the four most abundant of these fungi in terms of the percentage of the total number of spoiled berries. Occasionally the percentages recorded total more than 100, an apparent discrepancy which is accounted for by the fact that two or more fungi frequently develop from a single berry.

TABLE I. — *Most Important Fungi causing Storage Rot of Cranberries at Massachusetts State Experiment Bog, East Wareham, 1916.*

[Figures indicate per cent of total spoiled berries infected with each fungus.]

Storage Period.	Glomerella.		Phomopsis.		Sporonema.		Fusicoccum.		Sterile.	
	Blacks.	Howes.	Blacks.	Howes.	Blacks.	Howes.	Blacks.	Howes.	Blacks.	Howes.
Sept. 27–Oct. 11,	3	–	63	–	3	–	20	–	13	–
Oct. 14–18,	30	30	37	40	3	0	7	3	17	23
Oct. 11–25,	7	47	40	20	3	3	7	17	40	17
Oct. 18–Nov. 1,	15	47	36	7	15	0	33	30	0	13
Oct. 25–Nov. 8,	0	13	40	0	3	0	13	53	47	23
Nov. 1–15,	0	6	13	0	3	0	47	60	37	33
Nov. 8–22,	3	20	17	7	0	0	53	47	20	23
Nov. 16–30,	0	27	13	3	0	0	47	50	43	16
Nov. 23–Dec. 7,	0	3	17	3	0	0	40	70	47	20
Nov. 29–Dec. 13,	0	13	13	7	7	0	47	20	50	56
Dec. 6–20,	0	7	7	7	0	0	46	50	37	27
Dec. 13–27,	0	0	10	3	0	0	33	30	57	60

Comparing first the fungi found in the two varieties during this season it will be noted that Sporonema is much more abundant on the Early Blacks, though even on this variety it is not of very great importance. Phomopsis is considerably more common on the Early Blacks and Glomerella on the Howes. Fusicoccum (end rot) is an important storage rot on both varieties. Such differences as have been noted between the varieties may well be accidental. Howes usually bloom three to eight days later than Early Blacks, and thus might be in a condition of susceptibility to certain fungi at different times from the Blacks.

TABLE II. — *Cranberry Blooming Period at the Station Bog, East Wareham, Mass.*

YEAR.	Early Black.	Howes.
1913,	June 20–July 14	July 1–July 18
1914,	June 26–July 20	June 30–July 23
1915,	July 1–July 20	July 9–July 26
1916,	July 1–July 18	July 5–July 22
1917,	July 3–July 23	July 9–July 28
1918,	June 25–July 12	June 28–July 15

Certainly it would be unsafe to assume, without very extensive study, that either variety was especially susceptible to a given fungus.

The relative importance of the various fungi at different times during the storage season is most easily seen from the graphs, Figs. 1 and 2. In both varieties Phomopsis and Glomerella are most abundant early in the storage season, and become gradually less important. Fusicoccum, on the other hand, is relatively scarce early in the season, and becomes very much more abundant as the season advances, so that after the 1st of November end rot is more important than all the other rots combined. That this relation does not always hold is proven by the records of the succeeding year, but it seems probable that, in Massachusetts, end rot is the most serious cause of decay in stored cranberries during the latter part of the season. End rot in early stages can be identified on the fruit with a fair degree of certainty by careful observers, and its importance as a cause of loss in stored fruit has been emphasized by Mr. H. S. Griffith, chairman of the inspectors of the New England Cranberry Sales Company, in his report for 1919 (page 21).

The results of the second year's work as given in Table III show interesting resemblances to those of the previous year.

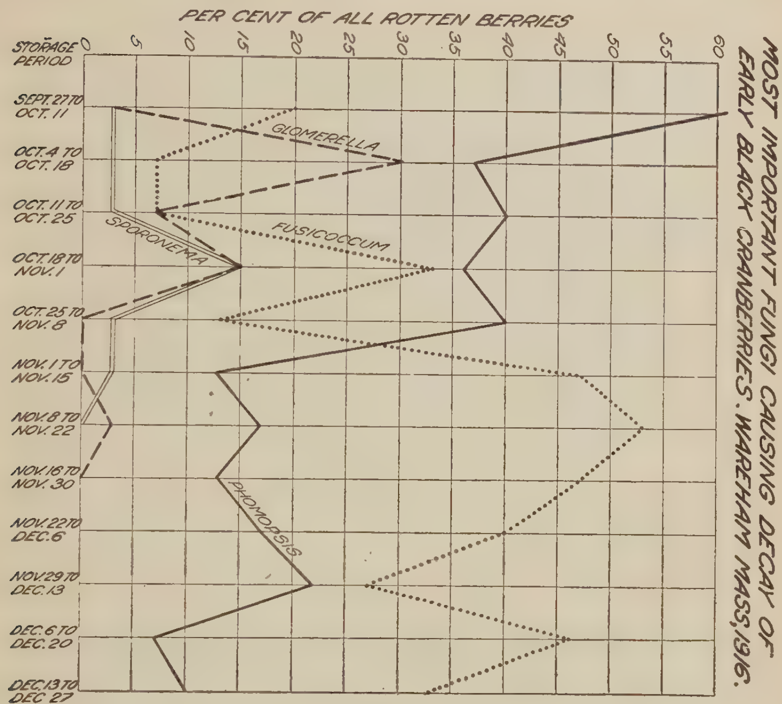

PER CENT OF ALL ROTTEN BERRIES
0
5
10
15
20
25
30
35
40
45
50
55
60
MOST IMPORTANT FUNGI CAUSING DECAY OF EARLY BLACK CRANBERRIES. WAREHAM MASS, 1916.
STORAGE PERIOD
SEPT. 27 TO OCT. 11
OCT. 4 TO OCT. 18
OCT. 11 TO OCT. 25
OCT. 18 TO NOV. 1
OCT. 25 TO NOV. 8
NOV. 1 TO NOV. 15
NOV. 8 TO NOV. 22
NOV. 16 TO NOV. 30
NOV. 22 TO DEC. 6
NOV. 29 TO DEC. 13
DEC. 6 TO DEC. 20
DEC. 13 TO DEC 27
GLOMERELLA
FUSICOCCUM
SPORONEMA
PHOMOPSIS

FIG. 1.

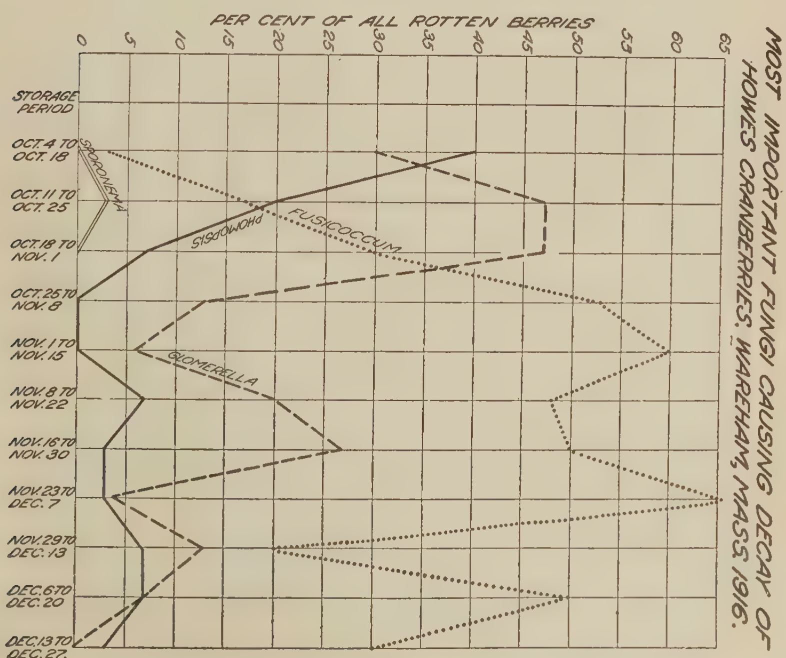

PER CENT OF ALL ROTTEN BERRIES
0
5
10
15
20
25
30
35
40
45
50
55
60
65
MOST IMPORTANT FUNGI CAUSING DECAY OF HOWES CRANBERRIES. WAREHAM, MASS 1916.
STORAGE PERIOD
OCT. 4 TO OCT. 18
OCT. 11 TO OCT. 25
OCT. 18 TO NOV. 1
OCT. 25 TO NOV. 8
NOV. 1 TO NOV. 15
NOV. 8 TO NOV. 22
NOV. 16 TO NOV. 30
NOV. 23 TO DEC. 7
NOV. 29 TO DEC. 13
DEC. 6 TO DEC. 20
DEC. 13 TO DEC. 27.
SPORONEMA
PHOMOPSIS
FUSICOCCUM
GLOMERELLA

FIG. 2.

TABLE III. — *Most Important Fungi causing Storage Rot of Cranberries at Massachusetts State Experiment Bog, East Wareham, 1917.*

[Figures indicate per cent of total spoiled berries infected with each.]

Storage Period.	Storage Temperature (Degree C.).	Glomerella.		Phomopsis.		Sporonema.		Fusicoccum.		Sterile.	
		Blacks.	Howes.	Blacks.	Howes.	Blacks.	Howes.	Blacks.	Howes.	Blacks.	Howes.
Before storage, . .	–	61	89	5	5	22	4	9	1	11	4
Storage ended Oct. 15,	20	12	76	30	3	15	0	21	3	15	7
	13[1]	23	88	40	4	20	0	13	1	11	8
Storage ended Nov. 12,	20	12	82	32	2	0	0	40	4	20	10
	18[1]	12	51	18	6	8	6	58	12	6	24
Storage ended, . .	20	2	43	10	3	3	3	67	18	9	23
	5[1]	1	31	3	6	2	3	58	36	11	10

[1] Estimated from outside temperature and from temperature of same room during the same periods of the previous year.

As in 1916 Sporonema is the least important of the four, and is found chiefly on the Early Blacks. Phomopsis is again more common on the Early Blacks, and Glomerella on the Howes; indeed, the contrast is more striking in 1917 than in 1916. During both years Phomopsis and Glomerella are more abundant early in the season, while Fusicoccum is rare early in the storage period and becomes more abundant later. The most unusual feature presented by the results is the very great abundance of Glomerella on Howes during 1917, and the relative scarcity of Fusicoccum.

So far as is now known infection by the various fungi causing decay of cranberries generally occurs before the berries are picked. That the development of the fungus is often delayed for some time is evident from the data here published, when it is recalled that in every case only apparently sound fruit was used for the storage test. The conditions necessary for the further development of a fungus already in the fruit or attached to the outer epidermis as a spore or appressorium are not yet determined. That it is not entirely a matter of condition of the berry is apparent from the fact that end rot, for example, becomes abundant on the Howes as soon as on the riper Early Blacks; and that it is not a matter of temperature appears (see Table III) from the fact that berries kept at 20° C. showed no marked difference in this respect from berries kept at lower temperatures.

BULLETIN No. 199.

DEPARTMENT OF POULTRY HUSBANDRY.

BROODINESS IN DOMESTIC FOWL.

DATA CONCERNING ITS INHERITANCE IN THE RHODE ISLAND RED BREED.

BY H. D. GOODALE, RUBY SANBORN AND DONALD WHITE.

INTRODUCTION.

Broodiness, as pointed out by Herrick (1907a, 1907b), is one phase of a recurring cyclical process in birds. In the domestic fowl when kept primarily for egg production, the instinct is not allowed to run its normal course, but is checked by suitable means in its initial objective stages. Some individuals, however, never exhibit the instinct. In this study of the inheritance of broodiness two categories of birds may be recognized, viz., those that exhibit the initial stages of broodiness, which are promptly checked, and those that do not exhibit any signs of broodiness. Broodiness is intimately connected with egg production, and, other factors being equal, its presence or absence determines the number of eggs laid, since, as shown later, its presence tends towards decreased production. A knowledge of its inheritance should show the steps necessary for its complete elimination from a flock.

The character, moreover, is not a superficial and unimportant one, but is a well-defined characteristic of the class Aves, and is essential for the survival of every species in the class. If the instinct were lost in a state of nature, without being replaced by some compensating mechanism,[1] the race would become extinct. In nature selection is constantly directed in favor of the character, since those individuals that lack it will leave no progeny, yet among domestic fowl we find entire races in which the character is lacking.

Poultrymen recognize both broody and non-broody races. The American breeds, *i.e.*, Plymouth Rocks, Rhode Island Reds and Wyandottes, and

[1] It is well known, of course, that the American cowbird and the European cuckoo have developed a compensating mechanism.

the Asiatics, *i.e.*, Langshans, Cochins and Brahmas, may be cited as examples of the former, while Hamburgs and Campines, and the Mediterranean breeds, *i.e.*, Leghorns, Spanish and Anconas, furnish examples of the latter. The distinction is based on the proportion between broody and non-broody individuals in each race, for some non-broody individuals occur among the broody races, while records are lacking to show that broody individuals are entirely absent from any of the non-broody races. The Leghorns are commonly regarded as a non-broody race, but as shown in Table VI, taken from the report of the fifth laying contest at Storrs (Kirkpatrick and Card, 1917), a considerable number become broody. It is a matter of common knowledge among poultry keepers that among the broody races there are considerable differences, some races, of which the Rhode Island Reds are an example, having an intense development of broodiness compared with others, such as the Barred Plymouth Rocks, in which the amount of broodiness is relatively slight.

There are few published reports on the character in the domestic fowl, though there is, of course, a considerable amount of matter scattered through the poultry literature, in which broodiness is mentioned in a more or less general way, but which is of no importance from the standpoint of this paper. Both Bateson's (1902) and Hurst's (1905) data showed that in a cross between a broody and non-broody race, broodiness was dominant, but they have published no further observations. Pearl (1914) has published certain data relating to broodiness, with which in general our data agree. A repetition of the same sort of material is unnecessary here. His methods of collecting the data and of handling the broody birds also are essentially the same as our practices in these respects. In general, our experience with this instinct agrees with his, except that there are two points for which different interpretations may be presented. On page 285 (*loc. cit.*) he makes this statement: "It appears to be the case that in the domestic fowl the brooding instinct has to a very large degree disappeared along with the fact of domestication." Evidently this author had not encountered a strain like our Rhode Island Reds, for such a statement would be impossible after an experience with such a strain. In the second place, we entertain some doubt as to the advisability of measuring the intensity of broodiness by the length of the nonproductive period associated with the objective symptoms of broodiness (*loc. cit.*, page 273), because, while the cessation of egg production coincides in nearly every instance with the onset of objective symptoms, the resumption of production is often delayed by other factors, among which may be noted the innate capacity for egg production and readiness to molt. In regard to its effect on egg production, Goodale (1918) makes the statement that the ratio between the egg production prior to the first broody period and that subsequent thereto is about 100:60.[1] Gerhartz (1914) has studied the metabolism of the broody hen in connection with his studies on the metabolism of the laying hen.

[1] The data on which this statement is based are given for the first time in Table VIII.

The Material and its Treatment.

The materials for the present study of the inheritance of broodiness are the pullet-year trap-nest records of the flock of Rhode Island Reds, bred at this station from 1913 to 1917, primarily to furnish data on the inheritance of fecundity. The usefulness of these data is limited in one important respect, since, as discussed in the section on variation, a year's record is not long enough to determine a hen's capacity for becoming broody. Limitations in housing capacity and labor have hitherto prevented the retention of non-broodies as long as was desirable. In the handling of the data, therefore, we have classified birds as broody or non-broody on the basis of the pullet-year records only, even though on this basis the non-broody class will contain more birds than it should. However, the theories of the inheritance of broodiness to which we have been led could not be substantiated from the available data, even if the difficulty under discussion were removed.

Recognition and Treatment of Broody Birds.

The recognition of a broody period is an easy matter with slight experience. The onset of broodiness is usually sudden. On the last visit to the trap nests late in the afternoon one or more birds are found that are very much disinclined to leave the nest. If they cluck and ruffle their feathers the diagnosis is certain, and the birds are removed to the broody coop to be "broken up." Sometimes part of the symptoms are lacking. In case of doubt the bird is merely removed from the nest. By the following afternoon, if she is really broody, all symptoms are well manifest. Mistakes are not easily made.

The broody coop in which the broody hens are confined, in order to prevent the instinct from running its normal course, is a box with slatted sides, top and bottom. The routine practice in dealing with broodies is to place all the broodies found in each pen in one of these coops. The same coop also receives the broodies on each of the two days following. Three days later the entire lot is released as a unit. Thus, the birds are confined from three to six days each, a period which is sufficient for the majority to "recover from the attack." A few, however, require a longer period of confinement. The confined broody individuals are supplied *ad libitum* with the same sort of food and water supplied the rest of the flock.

A bird must, as a rule, be classified either as broody or not broody, though in a few rare instances birds have exhibited a part of the broody symptoms only, as, for example, when a hen clucks and ruffles her feathers, but does not remain on the nest continuously, nor cease laying.

Variation in Amount of Broodiness.

A bird once broody may exhibit the character in various degrees which can be classified under two heads, — first, variation in the number of times a bird becomes broody in a period of given duration, usually the laying year; and second, variation in length and intensity of the individual broody periods. The latter is the less important of the two, for the length of time required by the vast majority of birds to "recover" from the attack is of comparatively small importance. To be sure, some birds take double the time that others require in "recovering," but it is an extreme case when more than a week is required, if no extraneous factors are present. Further, on forming a correlation table between number of days confined and subsequent egg production, it became evident that the coefficient of correlation (though not calculated) was so small that no relationship of importance existed between the subject and relative. The large factor in variability in broodiness is found in the variation in the number of times the broody cycle is repeated, as is shown later on.

Four sample egg records are shown here to illustrate individual variations in amount of broodiness. A numeral in a square indicates the hour at which an egg was collected; B. L., broody and placed in broody coop; A, released from broody coop; N, associated with a numeral, means that the bird visited the nest, but did not lay.

NO. 8314
PEN

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTALS	
SEPT.																																	
OCT.																			12	10			10.5		8	1	2.5		8	10.5	11.5	9	
NOV.	1	4		8	10.5	1		1	1	3	11.5	12 BL			A												N9	1	N1	7.5		12	
DEC.	4.5		7.5	1	N3.5	7.5	11.5	3		9	10.5	1	4		9	1		9	3		10.5	3		4.5		BL						18	
JAN.	A												N3	N1	N11.5 1		10.5	3		10.5		1		10.5	3		10.5	1		9	1	12	
FEB.	4			10.5	3		10.5	3		10.5	3 N4.5	BL		A												N4		10.5	3			9	
																																	60
MAR.		8.5	10.5	2		9	10.5	10.5	11.5	1	12	1	2	3		7	10.5 BL				A	N5		9	1		9	N1	2		7.5	19	
APR.	8.5	9.5	10	10	10	10	10.5	1 BL		A BL						A	10.5	2		7.5	9	9	8.5	8.5	N3	9x	10	10	2	BL		19	
MAY						A		1		7.5	11									10.5	9			10				9		2 N3	BL	8	
JUNE						A							11	10	1	1	1	1	2.5		7.5	1 BL					A					9	
JULY				9	11.5	2	3		7.5	11	1		8 BL					A						9	3		1	11	11	1		14	
AUG.										1		9	11	3		9	9	11	11	1		BL								A		9	
SEPT.						10	2		8.5	11	11	1	12	1	3 BL																	9	
OCT		1		9	3		9	10	11	11	11	1		1	BL																	10	
NOV																																	

YEAR'S TOTAL 157
(365 DAYS.)

FIG. 1.—Egg record of a very broody individual.

NO. B3700

PEN

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTALS	
SEPT.																																	
OCT.																																	
NOV.																					11.5		7	9.5	3		9	2		8		7	
DEC.	N3	N3.5	3		7.5	9.5	2.5		7.5	8	10	11	11.5	3			9	10	1	4			3		8	9.5	11	4		7.5	10	21	
JAN.	11.5	N3.5		7.5	8.5	10	11.5	4.5		8	9.5	10.5	2	3.5		8	11	11.5	1	4		8	9.5	11	10.5	10.5	11	N2.5	N4.5		8	23	
FEB.	11.5	11.5	4		8	10	11	N3		4		10.5	10	11.5	3.5			8.5	10	11.5	3.5		8.5	8.5	10	1	1.5	4.5				21	72
MAR.		8	2		8.5	10	N3	N3.5		8.5	1.5		8.5	10	1.5		8	9.5	12	11.5	11.5	11.5	N2	4 N5.5		8.5	10.5	4		N11	11.5	20	
APR.	3	3	N4	4		9.5	9.5	N2	N6		9.5	11	N2.5			10	11.5	2	12.5	1	2.5	4.5		N1	9.5	11	12	2.5 N5.5	BL			18	
MAY.				A		N11		N3		9.5	N2	N5.5		9	9	9.5	9.5	10.5	10.5	11.5	10	N3	11.5	10	9	2 N5.5	BL					13	
JUNE			A				N3.5	4.5		9.5	11.5	11.5	11.5	12.5	3		9.5	9.5	11	11	11	3 N5.5	BL				A	N4.5				13	
JULY		N9							2		9.5	2.5		11	12	3.5		9	10	9.5	9 N5.5	1.5C BL				A						11	
AUG.									N9	12			9.5	9.5	10.5	N3.5	4.5			1.5		8.5	10	10	10	1.5 NS	N2 BL					11	
SEPT.				A														N9.5	3		10	11	5		NS	3		9.5	9.5	11		8	
OCT.	11	11	11	1	12.5	3 N5	BL						A																			6	
NOV.																																	

YEAR'S TOTAL 172
(365 DAYS)

FIG. 2.—Egg record of a bird becoming broody about midseason.

NO. B 3226
PEN

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTALS	
SEPT.																																	
OCT.																																	
NOV.										N3												N10 N11.5 1.5		8.5	9	3		7.5	8.5	11		7	
DEC.	11	11	1.5	3		8.5	10	9.5	10.5	1.5		8	10	2		8	9	10	11	11	11	2	1	4		N4	8.5		10.5	3		24	
JAN.	8.5	10	1.5	3.5		8	10	11.5	N11 4		9.5	10.5	2	4.5		8	9.5	10	1	4		8	N1	11	3		8	9	9	11	11	25	
FEB.	1	4.5		8	9	10	11	11.5	1.5	2.5	5		N8.5	10	1	3.5		8.5	1	2		8	10.5	3.5		8.5	11.5	3.5				22	
																																	78
MAR.		8	10.5	10.5	1.5	3		8	10.5	11.5	N3		8.5	N3.5			N1	2		7.5	10	11.5	11.5	11.5	12	1.5	1	1.5	5.5		9.5	21	
APR.	12	12	2	2	6		9.5	11.5	2.5	2	5.5		9.5	11.5	12.5	1.5			9.5	11	2.5	4.5		9.5	11	11	12	12	12.5	5		25	
MAY		9.5	N12	12.5	3	3.5	N6		12.5 N6	4.5 N5.5	BL						A N6.5					N8	N8		9	10.5	N8 12	3.5	N4 6		9.5	12	
JUNE	11.5	12	2.5		N0.5	11 L0	12.5	4.5		11.5	3		11	5	N12.5	1	N9.5	12.5	N2.5	N9 N10.5 2		N8 N11 12.5	N8 N4	N8 N10.5 2	N12 3.5	N5	9.5	N8 N10.5 4.5	N9 N4	N8 10.5		19	
JULY	N12 2.5	N9 N6	9	11.5	3		9	N0 2	N9.5 N12 3.5	N9 N12.5	N0 11	12.5	5		10.5	1.5	5		11	3		11	3.5	N5	8	2	N4.5	9.5	2		9.5	22	
AUG.	1	3.5		9	11.5	5.5	N3	10.5	3		10.5	12	4.5	N3	9.5	2	4.5		11.5		N3.5	N2.5	11.5	4	N1	10	1.5		10.5	3.5	N1.5	20	
SEPT.	11.5	3.5 N5		10.5	3		11	5		11	5	N1	11	4.5		1.5																11	
OCT.					N11																											0	
NOV.																																	

YEAR'S TOTAL 208
(365 DAYS.)

Fig. 3.—Egg record of a bird becoming broody only once the first year, and that at midseason.

NO. B640

PEN

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTALS	
SEPT																																	
OCT.																											2			1		2	
NOV.	8.5	10	4.5		8	10	4.5		9	1.5	4		7.5	10	3		8	9	10	11	3		8	9	2		7.5	9.5	10			23	
DEC.	9	12				10.5	3		7.5	9	1	3		9	10	11	4		7	9	9.5	11	1	2.5		7	10.5	3.5	7		11	23	
JAN.	1	4		9	11	3		8	10	1.5	4		9	10.5	4		8.5	11	4		8	11	3.5		8.5	11	3		8.5	1.5	N3 4	24	
FEB.		10	1	4		11	3		8.5	2	2		8.5	12	4		10	3		8.5	3	4	9		11	4		9.5				20	92
MAR.	10	4		9	9.5	12	5		9.5	11	2		8	10	4		10	10			8.5	5		9	1.5		11	2		9.5	3	22	
APR.	6		12	5		11	5		3		2.5		2		12	1	4			3		12	5		10	6		2		11		18	
MAY		2		4		4		1		10	4			12		10	4	6		11	4		11	2	3	12	5		10.5	2	3	20	
JUNE		1		10	12	3		2		12	3		11		11	12	4		9.5	2		10	3				1	3				17	
JULY		5		3		N3 11	4.5		1		11		11	4		11	5		11			1		11.5	4		1.5		1		10	17	
AUG.	1		5	11	3		11		10	N10 3		11	3		10	2	5		11	1	5		10	1	5		10	3	N3 5	NBC BL	A	21	
SEPT.	BL		A																													0	
OCT.																																0	
NOV.																							10		10	1		10	1			5	

YEAR'S TOTAL 207

(365 DAYS)

FIG. 4.—Egg record of a bird becoming broody at the end of the laying year.

Figures 1, 2 and 4 are examples of variability in number of broody cycles. It will be observed that there is a period of production of variable length before the first broody period makes its appearance. This may come soon after production begins (Fig. 1), or may be delayed till near the end of the season (Fig. 4), or even till subsequent seasons. After the first broody period subsequent periods occur in fairly regular sequence, the cycle of broody, rest and production being repeated over and over. It is obvious, then, that the number of broody periods occurring during the first year will be determined in part by the time of year the first broody period occurs. After one broody period it becomes a question of the number of additional cycles that are added before a bird stops laying for the season. In the extreme case of Fig. 4, production was not resumed after the first broody period, which came late in the season.

In later years there has been much less regularity in the recurrence of the broody periods in that part of the flock bred specifically for increased egg production, but the parallelism does not necessarily mean that the latter has caused the former. It is noticeable that the broody periods are fewer in number and limited to the height of the broody season in many individuals, which afterward may become regular producers, without further evidence of broodiness in that season. For example, instances are quite common where a single broody period occurs in mid-season, and is followed by continuous production, as shown in Fig. 3. Sometimes there are two or even three such periods followed by continuous production. Occasionally some birds have broody periods occurring at rather irregular intervals.

When birds are kept through the second season it is found that some birds that did not become broody the first season may become broody at some point in the second season. One instance occurred where the bird did not become broody till the third season. Because of the physical limitations in the matter of plant equipment we are unable to give the exact percentage of birds not broody in their pullet year that became broody later on. We have, of course, the data for such birds as were kept over, but we do not believe it gives a fair picture of what will be found in large flocks. They are, however, fairly numerous. There is, moreover, some evidence that various lines behave unlike others in this respect. On the other hand, only four instances free from complications have occurred among our records of birds that were broody the first season but failed to become broody thereafter. It is clear that the pullet year is a good index of the presence of the broody instinct for those birds that actually become broody, but not as good an index for those that do not become broody.

This brief description of variation in amount of broodiness, together with the data given in Table VIII, is sufficient to give the reader a general idea of its nature. Further details are outside the scope of this paper.

Germinal Basis of Broodiness.

The normal or wild condition is the presence of broodiness, otherwise the race could not survive. Hence, any changes from the normal condition of those parts of the germ plasm which are responsible for the existence (as distinguished from amount) of broodiness will probably result in a failure in the appearance of the broody instinct. Broodiness may also, of course, fail to become manifest from non-genetic causes, and hence some genetically broody birds are recorded as non-broody. Non-broodiness, therefore, is a comprehensive term employed to describe the phænotypic condition resulting from several sorts of genetic differences. The situation is parallel, in certain respects, to that of eye color in Drosophila. Red eye is the normal or wild color. Changes in the germ plasm result in a host of other eye colors, which are all non-red. In like manner, from the genetic standpoint, all broody birds are presumably alike in their fundamental broody mechanism, except for the homozygous or heterozygous condition, and, of course, the presence of modifiers discussed in the next paragraph. Non-broody birds, on the other hand, may belong to quite different genotypes. It is, therefore, improbable that any one scheme can be applied to the inheritance of non-broodiness in domestic fowl. Indeed, the data given in Tables II and III indicate clearly that several types of non-broodies exist in the Rhode Island Reds. The presence of these types suggests that still different genetic types of non-broodies will be discovered in other breeds.

It seems clear on general grounds that a distinction must be made between the primary factors concerned with broodiness and modifying factors. The latter may act in various ways on the primary mechanism for the manifestation of broodiness, but they cannot act unless that mechanism is present. We may expect that such modifying factors will control the intensity of broodiness in either a plus or minus direction, and, extending this reasoning to its logical conclusion, such modifying factors may prevent entirely any manifestation of broodiness. Non-broodiness, therefore, may result from some genetic change in the secondary mechanism, as well as in the primary.

There are three possible sorts of matings (the male being treated as though capable of giving phænotypic expression to his genotypic constitution), viz., both parents may be broody, both non-broody, or one broody and the other non-broody. From each of these three possible matings there are three possible groupings of the female offspring, *i.e.*, (1) all may be broody, (2) all non-broody, and (3) part broody, part non-broody, as shown in Table I.

TABLE I. — *Kinds of Offspring expected from all Possible Kinds of Matings.*

PARENTS.	Offspring.
Both parents broody, ...	All broody. All non-broody.* Part broody, part non-broody.
Both parents non-broody, ...	All broody.* All non-broody. Part broody, part non-broody.
One parent broody, the other non-broody, . . .	All broody. All non-broody.* Part broody, part non-broody.

Of the nine possible groupings between parents and offspring, six have been realized in our experience. Those marked with an asterisk (*) have not been realized. Two of the three unrealized possibilities should be realized eventually, and the third, all non-broody offspring from broody parents, is not expected, as is explained beyond.

The preceding table, as well as the ratios in which the offspring occur, Table II, does not agree with the assumption that broodiness is a simple Mendelian dominant and non-broodiness a simple recessive in all instances as Hurst (1905) supposed. If non-broodiness were a simple Mendelian recessive, then the son of a non-broody hen should throw either all non-broodies or half non-broodies when bred to non-broodies, but this does not always happen. Moreover, the establishment of a non-broody strain should have been a much simpler matter than it has proved.

TABLE II. — *A Comparison between Observed and Theoretical Ratios, assuming that Two Factors, A and C, must both be present in order that an Individual may become Broody.*

Father's Band Number.	1915.							1916.								1917.							
	Number of Mothers.			Offspring.				Father's Band Number.	Number of Mothers.			Offspring.				Father's Band Number.	Number of Mothers.			Offspring.			
				Observed Ratio.		Expected Ratio.						Observed Ratio.		Expected Ratio.						Observed Ratio.		Expected Ratio.	
	Non-broody.	Broody.	Total.	Non-broody.	Broody.	Non-broody.	Broody.		Non-broody.	Broody.	Total.	Non-broody.	Broody.	Non-broody.	Broody.		Non-broody.	Broody.	Total.	Non-broody.	Broody.	Non-broody.	Broody.
68,	1	3	4	0	9	0	9	274	0	2	2	0	8	0	8	3003	4	1	5	23	1	22⅛	1⅞
A143,	1	2	3	1	9	0	10	3617	0	5	5	6	24	3½	26½	5470	4	0	4	13	5	13	5
228,	0	3	3	0	5	0	5	4312	0	1	1	0	8	0	8	5581	0	1	1	0	4	0	4
269,	3	10	13	7	40	6	41	4354	1	4	5	5	32	2	35	7727	0	2	2	1	3	¾	3¼
270,	0	2	2	0	6	0	6	4378	0	4	4	6	22	5½	22½	7745	0	3	3	4	10	2½	11½
271,	0	4	4	2	15	⅞	16⅛	4723	0	6	6	15	59	16⅞	57⅛	7931	0	1	1	2	1	1 5/16	1 11/16
272,	0	1	1	0	2	0	2	4786	0	2	2	2	6	⅞	7⅛	8027	2	6	8	30	39	27½	41½
274,	4	5	9	0	43	0	43	4882	0	1	1	5	20	6¼	18¾	8095	1	3	4	3	4	2 13/16	4 3/16
A323,	0	1	1	0	1	0	1	5077	0	3	3	2	10	2¼	9¾	8097	0	5	5	21	22	17¼	25¾
619,	0	2	2	0	3	0	3	5240	0	1	1	0	7	0	7	8147	2	5	7	15	33	18	30
2313,	0	5	5	1	30	⅞	30⅛	5470	0	1	1	1	2	1½	1½	8217	0	3	3	0	9	0	9
2539,	0	1	1	0	1	0	1	5477	0	2	2	0	15	0	15	8422	1	2	3	7	4	6½	4½
2914,	1	2	3	2	7	2⅞	6⅛	5581	0	7	7	2	42	1½	42½	8528	1	5	6	27	32	28¼	30¾
3003,	4	1	5	11	3	11⅜	2⅝	5584	0	4	4	3	35	0	38	8761	0	4	4	9	15	7 5/16	16 11/16
3533,	0	4	4	1	11	7/16	11 9/16	5642	1	0	1	0	2	0	2	9305	0	2	2	2	5	1½	5½
3617,	1	10	11	1	38	1¼	37¾	5776	0	1	1	0	8	0	8	9752	6	5	11	57	16	48⅜	24⅝
4128,	0	4	4	2	10	1½	10½	6265	0	3	3	1	19	0	20	–	–	–	–	–	–	–	–
4167,	3	4	7	5	52	5½	51½	6373	0	4	4	0	22	0	22	–	–	–	–	–	–	–	–
4265,	0	3	3	2	16	2½	15½	6781	1	3	4	14	24	16⅜	21⅝	–	–	–	–	–	–	–	–
Brown,	0	1	1	0	3	0	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
McLean,	0	4	4	1	13	0	14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Several factorial explanations of the observed ratios between broodies and non-broodies in the several families can be developed, but choice among such explanations cannot be made because of the small size of the individual families, *i.e.*, the offspring of a single mother. Nor are any of them of value save as working hypotheses. The one on which Table II is based is presented simply to show that a close agreement between theory and fact is possible, and this theory was chosen for presentation because it gives a slightly better agreement between observed and theoretical rations, with one partial exception, than the others. This theory assumes that the appearance of broodiness in Rhode Island Reds requires the simultaneous presence of two factors, designated A and C, in either homozygous or heterozygous condition. A better fit in the case of the partial exception can be secured by assuming that there is also a dominant factor (presumably a modifier) for non-broodiness, which may be designated as N. Non-broodies, therefore, may be of numerous genetic types, the homozygous forms being NNAACC, nnAAcc, nnaaCC; and nnaacc, where A and C, respectively, represent the factors (condition of germ plasm) necessary for broodiness. A broody bird, then, in homozygous form must be nnAACC. As shown by Table III, which gives the theoretical ratios expected on both the NNAACC and AACC theories, it will be seen that matings between birds of the same phænotype may give several different ratios, including those in which the proportions between broody and non-broody birds are reversed. Thus (NNAACC theory) broody x broody may give 3 broody to 1 non-broody, or it may give 1

TABLE III.—*The Theoretical Ratios resulting from Matings of Different Types, arranged by Ratios.*

[A ratio appears only once under its respective theory.]

Parents.	NNAACC Theory. Progeny.		AACC Theory. Progeny.	
	Non-broody.	Broody.	Non-broody.	Broody.
Broody × broody,	7	9	7	9
Non-broody × non-broody,	55 29 15 64	9 3 1 0	16	0
Broody × non-broody,	23	9	5	3
Broody × broody, broody × non-broody,	0 1	64 3	1	3
Broody × non-broody, non-broody × non-broody.	1 13 7	1 3 1	1 3	1 1
Broody × broody, broody × non-broody, non-broody × non-broody.	5 3	3 1	0	16

broody to 3 non-broody, exactly reversing the ratio, as has occurred in the detailed data from which Table II was compiled. It should be stated that while families showing the extreme ratio of 15 non-broody to 1 broody have not been encountered, several instances of the 7:1 ratio have been observed.

The only evidence at present available in support of either of these schemes is furnished by the ratios between the broody and non-broody members of the several families (Table II). N, if it represents a real condition of the germ plasm, occurs relatively infrequently in the flock at present. Practically all the observed ratios, except the partial exception mentioned, can be accounted for if N is omitted.

It is also possible to modify the AACC theory, by assuming that A is sex linked, though no evidence of sex linkage other than an agreement between the observed and theoretical ratios has been noted. Doubtless other schemes could be devised that would also account for the ratios.

Although the ratios themselves could perhaps be explained as chance deviations from monohybrid ratios (though this is doubtful in some instances), or as the result of errors of classification of individuals through failure to manifest the genotypic condition phænotypically, the moment lines of descent are established it becomes clear that a monohybrid explanation does not fit the facts. The data have been worked over in an attempt to apply the monohybrid scheme, *i.e.*, broodiness due to a single dominant factor, but without success. See, for example, the history of male No. 3003 and his offspring, page 107.

In order to establish the existence of any of the schemes under discussion certain results of critical importance must be obtained. Thus, the discovery of a family consisting of all non-broody offspring from the mating between a non-broody and a broody is required to demonstrate the presence of a dominant factor for non-broodiness, while a mating between two non-broody birds that gives all broodies is required as proof of the AACC theory (or a theory of the same order). The ratios at hand indicate the possibility that several genetic types of non-broodies coexist in our strain. One possibility only seems to be excluded if the schemes outlined represent the facts, for one need never expect to find a pair of broody birds that produces all non-broody offspring, because such a result would mean two distinct types of broodies which mutually inhibit each other.

Modifying Factors for Broodiness.

The possibility that the non-broodies dealt with in these experiments are not due to changes in the primary genes concerned with broodiness, but are due to changes in modifying genes, cannot be excluded. As we have worked over the records, the impression has been strong that we are not dealing with a real absence of broodiness so much as with delay in the appearance of broodiness. Unfortunately the present data are inadequate to settle this point. Nor is it likely that we shall have suitable data in the near future, because the somatic manifestations of broodiness,

i.e., the number of times a bird becomes broody as well as the ease with which she is broken up, vary considerably, as already described. Since the chief reason for this variability is found in the number of times a bird becomes broody, which in turn is so thoroughly interwoven with egg production, the same practical difficulties, *i.e.*, disease control, that at present prevent a complete analysis of the inheritance of fecundity also prevent the determination of the hereditary factors involved in degree of broodiness.

The Production of a Strain of Low Degree of Broodiness through Selection.

Two lines of selection have been under way, — one for the elimination of broodiness, the other for its development to a high degree, equal to or greater than that observed in the case of Fig. 1. Because most of our facilities were needed in other directions, little has been done with the plus line beyond its maintenance. The minus line, however, has been closely involved with the problem of securing increased egg production, since absence of broodiness tends toward higher production, other things being equal. Until 1917 this line had been also carried on in a very small way, the general policy being to mate the son of a non-broody bird to non-broodies, on the hypothesis that broodiness is a simple Mendelian dominant, and non-broodiness a recessive. As a result of the early matings a male was obtained that appeared to be a homozygous recessive, since he threw no broodies from non-broody mothers. In 1917 this male, No. 3003, with his son, No. 5470 out of a non-broody hen, and grandson, No. 9752 (mother broody once in her third year), also supposed to be homozygous recessives, were mated to all the non-broody hens available. Some of these, however, became broody the second year. The results of the experiment, given in Tables IV and V, show that non-broodiness is not always a simple Mendelian recessive, since the son and grandson failed to breed true, even with those birds that never became broody. This

TABLE IV. — *The Progeny of Three Supposedly Non-broody Males distributed according to their Mother's Broody History.*

Male.	Mothers not Broody.			Mothers known to be Broody after Pullet Year.			Mothers Broody in Pullet Year.		
	Number of Mothers.	Daughters not Broody.	Daughters Broody.	Number of Mothers.	Daughters not Broody.	Daughters Broody.	Number of Mothers.	Daughters not Broody.	Daughters Broody.
No. 3003, ...	4	19	0	–	–	–	1	4	1
No. 5470 (son of No. 3003),	3	9	1	1	4	4	–	–	–
No. 9752 (son of No. 5470),	6	27	9	1	1	0	4	29	7

TABLE V. — *"Non-broody" Lines, 1917–18.*

[Daughters of males No. 3003, No. 5470 and No. 9752.]

	Number of Daughters.	Daughters not Broody.		Daughters Broody once.		Daughters Broody more than once.		Total Broody Daughters.	
		Number.	Per Cent.	Number.	Per Cent.	Number.	Per Cent.	Number.	Per Cent.
Mothers not broody in pullet year.	72	58	80.55	9	12.50	5	6.94	14	19.44
Mothers broody once in pullet year.	34	28	82.35	1	2.94	5	14.71	6	17.65
Totals, . . .	106	86	81.13	10	9.43	10	9.43	20	18.87

conclusion is supported by the ratios observed in other matings which have already been commented upon. However, the amount of broodiness in the first laying year is much reduced compared with the flock from which it originated, the data on this point being given in Table VII, Table VIII, item 4, and Table IX. A comparison with the published results of the laying contest at the Connecticut Agricultural Experiment Station shows that our foundation stock had broodiness developed to a higher degree than any of the breeds studied at Storrs, and that our non-broody

TABLE VI. — *Broodiness in the Several Breeds at the Storrs Contest of 1915–16, compared with Three Flocks at the Massachusetts Agricultural Experiment Station.*

Breeds.	Number of Birds.	Broody.		Average number of Times Broody per Broody Hen.	Average Number of Times Broody for All Birds in Flock.	Average Number of Days in Broody Period.	Average Number of Days spent in Broodiness by each Broody Hen.	Average Number of Days spent in Broodiness per Hen, per Year, all Birds included.
		Number.	Per Cent.					
Storrs.								
Plymouth Rocks, .	151	67	44.4	2.8	1.2	21.2	59.9	26.6
Wyandottes, . .	151	87	57.6	2.5	1.4	19.4	47.6	27.4
Rhode Island Reds, .	183	120	65.6	2.8	1.8	21.3	60.2	39.5
White Leghorns, .	315	43	13.6	1.3	.2	22.7	29.6	4.0
Massachusetts.								
Rhode Island Reds, 1912–13.	125	112	89.6	4.4	3.9	19.7	74.8	65.8
Rhode Island Reds, 1913–14.	78	71	91.0	5.4	4.9	16.3	78.8	68.7
Rhode Island Reds, 1917–18, "non-broody" line.	106	20	18.9	1.9	.4	20.9	37.0	10.6

TABLE VII. — *Number and Per Cent of Birds Broody and not Broody in Pullet Year in Three Flocks of Rhode Island Reds.*

Date.	Total Birds.	Broody.		Not Broody.	
		Number.	Per Cent.	Number.	Per Cent.
1912–13, ...	125	112	89.60	13	10.40
1913–14, ...	78	71	91.03	7	8.97
1917–18, ...	106	20	18.87	86	81.13

lines, derived from this extremely broody stock, exhibited a low degree of broodiness surpassed only by the Leghorns (Table VI). The most significant data on this point are given in the third and last columns of Table VI. Table VII shows the relation between the number of broody birds and those not broody for the flocks of 1912–13, 1913–14 and 1917–18. The flock of 1912–13 was the foundation stock.

Tables VIII and X give a further comparison between the broody birds of the flocks of 1913–14 and 1917–18.

TABLE VIII. — *Statistical Constants for Various Broody Characters for the Flock of 1913–14, and the Non-broody Flock of 1917–18.*

		Number of Instances or Individuals.		Mean.		Standard Deviation.		Coefficient of Variation.	
		1913–14.	1917–18.	1913–14.	1917–18.	1913–14.	1917–18.	1913–14.	1917–18.
1	Number of broody periods per individual.	71	20	5.39±0.23	1.90±0.17	2.87±0.16	1.14±0.12	53.24±3.77	59.78±8.35
2	Length of broody periods (days), . .	327	34	16.28±0.34	20.91±0.95	9.04±0.24	8.22±0.67	55.60±1.85	39.32±3.68
3	Amount of broodiness in each individual (broodies only) (days).	68	20	78.84±4.03	37.00±3.63	49.27±2.85	24.06±2.57	71.68±5.90	65.02±9.42
4	Amount of broodiness in each individual (entire flock) (days).	78	106	68.73±3.28	10.63±1.08	42.95±2.32	16.46±0.76	62.49±4.50	154.83±17.27
5	Days in initial laying period, . . .	71	20	118.67±4.23	170.50±8.42	52.82±2.99	55.86±5.96	44.51±2.98	32.76± 3.85
6	Eggs in initial laying period, . . .	71	20	80.64±2.85	101.50±3.84	35.66±2.02	25.48±2.72	44.22±2.95	25.10±2.84
7	Per cent production in initial laying period.	71	20	67.89±0.99	61.00±1.68	12.38±0.70	11.17±1.19	18.24±1.07	18.31± 2.02
8	Days in each laying period, . . .	327	34	18.84±0.40	36.85±2.98	10.85±0.29	25.80±2.11	57.60±1.96	70.00± 8.06
9	Eggs in each laying period, . . .	327	34	13.96±0.19	21.26±1.52	5.21±0.14	13.12±1.07	37.32±1.11	61.72± 6.70
10	Per cent production in each laying period,	327	34	78.41±0.53	64.91±3.09	14.24±0.38	26.70±2.18	18.16±0.49	41.13± 3.89
11	Time spent in laying periods annually by each individual (days).	68	20	90.75	62.75	–[1]	–[1]	–[2]	–[3]
12	Average length of broody cycle (days), .	327	34	35.02±0.56	57.71±2.98	15.15±0.40	25.72±2.10	43.26±1.34	44.57± 4.31
13	Per cent production in broody cycle, .	327	34	41.50±0.43	35.94±1.54	11.55±0.30	13.29±1.09	27.83±0.79	36.98±3.41

[1] Standard deviation not calculated. [2] Range 9–188. [3] Range 16–114.

DEFINITION OF TERMS USED IN TABLE VIII.

2. In reckoning the number of days in a broody period the first day without production is taken as the first broody day, while the last day counted is the day before production begins again. The object here is to measure the length of the non-productive period originating with broodiness, but not the intensity of broodiness itself. This definition includes instances in which the resumption of production is delayed long after its normal time because of the interference of factors not concerned with broodiness. Some limitation to the number of days included in the non-productive period is desirable, but the only one employed thus far is the exclusion of broody periods that end the annual cycle of production, and whose length cannot be ascertained.

5, 6, 7. The initial laying period begins with the first egg laid, and ends with the last egg laid before the first broody period.

8, 9, 10. A laying period begins with the first egg laid after a broody period, and ends with the last egg laid before the subsequent broody period.

12, 13. A broody cycle is defined as a broody period plus the following laying period. The incomplete cycles formed by a terminal broody period are rejected in calculating the constants. It is, of course, possible to treat the broody cycle somewhat differently, by defining it as a laying period plus the subsequent broody period. Biometrical constants were calculated for each method of treatment, but since the results proved to be essentially the same, if the initial cycle is omitted, only one set of constants is given in the table.

Constants differing slightly from those given in the table are obtained, if, instead of employing each instance separately in the calculations, the average for each individual bird is employed. Whether the instance or the average for each individual bird should be used in calculating the constants depends on which one occupies the center of interest, but whichever method is used, the primary purpose for which this table is presented is not affected. The inconsistencies in the number of individuals occur because it is often possible to determine a character in one individual but not in another. Thus, every bird that becomes broody can be counted, but if a bird becomes broody but once, and does not lay again until the following year, the length of her broody period cannot be measured, and so is omitted in calculating the constants.

Taking the means (Table VIII) as the basis of comparison, it is clear that the birds of the "non-broody" lines becoming broody in 1917–18 had the character much less intensely developed than the broodies of the flocks of 1912–13 and 1913–14 from which they originated. The mean number of times each broody bird became broody is 1.90 against 5.39. Though the average length of each broody period is longer (Table VIII), the total time spent in broodiness by each broody bird is about one-half that of the broodies of the flock of 1913–14. If the entire flocks of each year (*i.e.*, if the non-broody birds are included in calculating the means) are compared with each other the following significant results are obtained (Table IX): —

TABLE IX. — *A Comparison of the Amount of Broodiness in the Foundation Flock, 1912–13, and their Immediate Unselected Descendants, 1913–14, with their Descendants selected for the Absence of Broodiness, 1917–18.*

DATE.	Number of Birds.	Mean Number of Days spent in Broodiness.	Mean Number of Times Broody.
1912–13, ...	125	65.81	3.88
1913–14, ...	78	68.73	4.91
1917–18, ...	106	10.63	.36

A comparison between the two flocks in respect to egg production (Table VIII) shows that while the 1917–18 flock laid somewhat less rapidly than the 1913–14 flock, the first broody period came later in life (Table X). The mean date of the first broody period is April 18 for the 1913–14 flock, and June 7 for the 1917–18 flock. The 1917–18 flock has a slower rate of production, as shown by the lower percentage production in the initial laying period as well as the later laying periods. On the other hand, the length, both of laying periods and broody periods, is longer

TABLE X. — *Seasonal Distribution of Broodiness in the Flock of 1913–14, and in the Broodies occurring in the Non-broody Lines, 1917–18.*

	Month.	Month in which Individual Broody Periods begin.				Month in which First Broody Period of Each Individual begins.				Month in which Last Broody Period of Each Individual begins.				Month in which Median Broody Period of Each Individual begins.			
		1913-14.		1917-18.		1913-14.		1917-18.		1913-14.		1917-18.		1913-14.		1917-18.	
		Number.	Per Cent.	Number.	Per Cent.	Number.	Per Cent.	Number.	Per Cent.	Number.	Per Cent.	Number.	Per Cent.	Number.	Per Cent.	Number.	Per Cent.
1	November,	–	–	–	–	–[1]	–[1]	–	–	–	–	–	–	–	–	–	–
2	December,	5	1.30	–	–	5	7.04	–	–	–	–	–	–	–	–	–	–
3	January,	4	1.04	–	–	3	4.23	–	–	–	–	–	–	–	–	–	–
4	February,	8	2.08	–	–	3	4.23	–	–	–	–	–	–	–	–	–	–
5	March,	19	4.94	–	–	10	14.08	–	–	–	–	–	–	–	–	–	–
6	April,	41	10.68	4	10.53	21	29.58	4	20.00	–	–	–	–	.5	.70	.5	2.50
7	May,	67	17.45	11	28.95	16	22.54	8	40.00	3	4.23	5	25.00	10.5	14.79	6.0	30.00
8	June,	64	16.67	6	15.79	9	12.68	2	10.00	4	5.63	3	15.00	34.0	47.89	5.0	25.00
9	July,	53	13.80	8	21.05	2	2.82	3	15.00	2	2.82	5	25.00	18.0	25.35	5.5	27.50
10	August,	48	12.50	4	10.53	–	–	3	15.00	6	8.45	2	10.00	5.0	7.04	2.0	10.00
11	September,	43	11.20	4	10.53	1	1.41	–	–	26	36.62	4	20.00	2.0	2.82	.5	2.50
12	October,	25	6.51	1	2.63	–	–	–	–	23	32.39	1	5.00	–	–	.5	2.50
13	November,	7	1.82	–	–	1	1.41	–	–	7	9.86	–	–	1.0	1.41	–	–
	Totals,	384	99.99	38	100.01	71	100.02	20	100.00	71	100.00	20	100.00	71.0	100.00	20.0	100.00

[1] Very few birds laying.

in this flock than in that of 1913–14. Just what this means is uncertain. The longer laying periods may be taken as resultant of the reduced tendency toward broodiness, but this is not true for the longer broody periods. The latter may be connected with the slower rate of production.

The experiments in eliminating broodiness are being continued, but a change in the plan of the experiment, to permit of the fusion of the non-broody line with another line known as the high-producing line, has been made. The fusion appears at date of this writing to be accomplished.

Broodiness, in its various sub-characters and in the associated periods of egg production, is decidedly variable as judged by the several coefficients of variation given in Table VIII. Some of the sub-characters are much more variable than others. While some of the characters associated with broodiness are of the same order of variability in the two flocks studied, others are quite unlike, sometimes one and sometimes the other flock being the more variable. The details are best obtained from Table VIII.

Relation between Birds of a Low Degree of Broodiness and Absence of Broodiness.

Some evidence exists that birds that become broody once during the pullet year are not genetically different from those that do not become broody, since the number of broody offspring from each sort of female is approximately the same, as is shown in Table XI. On the other hand,

Table XI. — *A Comparison between the Number of Broody Offspring from Non-broody Mothers with the Number from Mothers Broody once, the Sires being the Same for Both Lots of Offspring.*

	Number of Mothers.	Broody Offspring.		Non-broody Offspring.	
		Number.	Per Cent.	Number.	Per Cent.
Not broody,	15	14	19.45	58	80.55
Broody,	3	6	17.65	28	82.35

the daughters of birds broody once are somewhat more broody than the daughters of birds not broody at all, as shown in Table XII, which gives a comparison between 14 broody daughters of non-broody mothers and 6 broody daughters of mothers that became broody once, the sires being the same for both lots. It is shown by the per cent production, for both the initial laying period and the subsequent laying periods, that the two sets of birds are about equal in their ability to produce eggs. The daughters whose mothers became broody once were, however, somewhat more broody than the daughters of hens that did not become broody at all, as shown by the length of the initial laying period, the number of broody periods per individual, and the length of the broody periods. Though

in this experiment the daughters of non-broody hens are less broody than the daughters of hens broody once, it would be unwise to generalize such a conclusion, because of the very small number of individuals involved.

TABLE XII. — *A Comparison of the Amount of Broodiness in the Daughters of Non-broody Hens with those whose Mothers became Broody once.*

	Mothers not Broody in Pullet Year.		Mothers Broody once in Pullet Year.	
	Number of Instances or Individuals.	Mean.	Number of Instances or Individuals.	Mean.
Days of broodiness per individual,	14	31.64	6	49.50
Days in each broody period,	22	18.26	12	24.25
Broody periods per individual,	14	1.79	6	2.17
Days in initial laying period,	14	181.36	6	145.67
Eggs laid in initial laying period,	14	106.93	6	85.83
Per cent production in initial laying period per individual.	14	60.86	6	60.27
Days in each laying period,	22	38.23	12	34.50
Eggs laid in each laying period,	22	21.95	12	19.83
Per cent production in each laying period,	22	65.20	12	64.70
Eggs in each laying period per individual,	14	25.44	6	21.37

Since some birds become broody in their second or third laying years that did not become broody in the first year, the question may be raised as to whether or not a hen may ever be so constituted that it is impossible for her to become broody. We have kept a few hens for four years without evidence of broodiness, but this may not mean that these birds might not have become broody if the proper stimulus had existed. There is the further question as to whether the designation "non-broody" has been accurately used for birds not broody in their pullet year. It might be better to regard such cases as instances of delayed broodiness rather than of the actual absence of broodiness. The delay in the appearance of broodiness in some individuals certainly complicates matters greatly.

The Interrelation of Several Broody Characters.

The interrelations of several of the broody characters have been studied in the 1913–14 flock by means of the coefficient of correlation. It should, perhaps, be pointed out that the coefficient of correlation does not measure the relationship between the characters as such, but relationship between the numerical occurrence of such characters in the flock studied. This limitation in the use of the coefficient of correlation is often forgotten. Thus it is found that r between number of eggs laid in a year and total days spent in broodiness is $+.1677 \pm .0742$. This value, as shown by

its large probable error, is not significant statistically, but, ignoring the error, may perhaps indicate that broodiness is an advantage, since, on the average, those birds spending the most time in broodiness are the heaviest layers. On the contrary, it is known from a study of other data that the very best layers cannot spend much time in broodiness. The interpretation we give this value is that those birds whose laying year begins earliest and stops latest get in more broody periods, other things being equal, than birds whose laying year is shorter.

If an index of production of high value is desired, it is found in the initial laying period, for here the correlation between the length of the period and number of eggs produced is very high, viz., $+.8843 \pm .0210$, a value, moreover, that indicates good homogeneity in rate of production in this flock.

In this flock there is a pronounced negative correlation between egg production during the laying periods and number of broody periods, the coefficient of correlation being $-.3453 \pm .0716$, indicating that those birds that are very broody tend to lay less eggs between broody periods than those having a less number of broody periods. On the other hand, there is no relation between the average (*i.e.*, for one individual) length of laying periods or the eggs produced in such periods and average length of broody periods, since in the first case $r = -.0130 \pm .0818$, and in the second case $r = -.0013 \pm .0818$.

While the above statements hold true for average values, if the coefficient of correlation is determined between the length of a laying period or its egg production and the length of the broody period immediately subsequent thereto, a marked negative correlation is found, being $-.2899 \pm .0415$ in the first instance, and $-.3715 \pm .0345$ in the second. The disagreement between the values obtained when each laying period is correlated with its subsequent broody period, and that found when the average value for each bird is used, is due to a shortening of the laying period and a lengthening of the broody period as the season progresses. This is clearly shown on the individual records.

If, instead of taking a laying period and its subsequent broody period, a broody period is paired with the laying period following, little or no relationship is indicated, for r between length of broody period and subsequent laying period is $-.0222 \pm .0388$, while between length of broody period and subsequent egg production it is only slightly greater, being $-.0799 \pm .0372$.

The interrelationships discussed in the two paragraphs preceding may perhaps be interpreted to mean that heavy laying tends to suppress broodiness, or, at least, that in the flock studied, those birds that laid most heavily had shorter broody periods than those laying less heavily, the tendency to heavy production in such birds enabling them to get back more quickly into production than those in which the tendency was less strong. Longer broody periods, however, and their accompanying element of rest did not conduce to heavier production, a view contrary to that held by most poultrymen.

Summary and Conclusions.

The working hypothesis is adopted that —

1. Broodiness depends upon the presence of a "complete mechanism" in the individual, from which it follows that the absence of broodiness depends upon the loss of some essential part of this mechanism, or upon its inhibition by some secondary factor.

2. The inheritance of broodiness may be expected to vary from flock to flock.

3. In the flocks studied, non-broodiness appears to result from the loss of one or both of two genes from the complete germinal complex, while there is some evidence that a dominant inhibitor may also exist in the germ plasm of these flocks.

4. By suitable breeding methods it has been possible to develop quickly a strain of low degree of broodiness from a strain with a very high degree of broodiness.

5. Statistical constants for certain broody characters are given.

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BULLETIN No. 200.

DEPARTMENT OF CHEMISTRY.

THE NUTRITIVE VALUE OF CATTLE FEEDS.

2. OAT BY-PRODUCTS FOR FARM STOCK.

BY J. B. LINDSEY AND C. L. BEALS.

A. The Process of Manufacture.

Oat feed is the residue from the oat meal mills engaged in the preparation of oat products for human consumption.

In the milling process the first step consists in separating the light and double oats and other cereal seeds, as well as sticks and straw, from the oats suitable for human consumption. These latter oats are divided into two or more grades, depending upon size, in order to gain efficiency in milling, and are then roasted or dried in open pans over fire with constant stirring, in order to drive off as much moisture as possible. From the roasters the oats are run over coolers and dusters, and then to the stones which remove the hulls. This latter process, called the first milling or hulling, does not remove all of the hulls, and the unhulled oats are subjected to a second milling to complete the process.

Mill run oat feed contains the hulls, usually reground, together with the middlings and dust removed in the first milling. The residue from the second milling contains a much larger proportion of middlings, and, together with some middlings recovered in cleaning the rolled oats, is used in calf meals and poultry feeds, and is not returned to the oat feed.[1] It is understood that *mill run oat feed*, as above described, should be a comparatively uniform product, especially as produced at the larger plants in the United States. On the other hand, small Canadian mills, because of a less efficient process of separation, are likely to put out an oat feed of better quality than the average run from the larger American mills.

[1] One large manufacturer states that in its process the middlings and dust from the second milling are also incorporated in the oat feed, and that the material used in calf and pig meals represents the fine oat particles and chips made in cutting groats or shelled oats, together with the fine flakes that come from the rolled oat aspirators, and also the pieces of groats which are unsatisfactory for rolling on account of being broken. It seems reasonable to assume that the process of manufacture may vary somewhat in different establishments.

B. Analyses of Oat By-Products.

In view of the constant increase in the cost of hay and all kinds of concentrates, it was believed that a study of the value of oat by-products was worth while. A visit was therefore made by Mr. P. H. Smith to one of the mills of the Quaker Oats Company and of the H–O Company, the process of manufacture observed, and samples secured for analysis, which were declared by the manufacturers and believed by us to be representative. In addition, several lots of oat feed were shipped us at our request for the purpose of conducting digestion and feeding experiments. The analyses of all of these samples follow: —

Table I. — *Composition of Oat By-Products.*

(*a*) *Oat Hulls.*

Sample No.	Source.	Water.	Ash.	Protein.	Fiber.	Extract Matter.	Fat.	Total.
1	H–O Company (unground), . .	3.82	6.65	.96	33.18	54.99	.40	100
2	Quaker Oats Company (ground), .	5.04	6.15	2.01	31.08	54.78	.94	100
	Average,.	4.43	6.40	1.49	32.13	54.88	.67	100

(*b*) *Oat Middlings and Dust.*

Sample No.	Source.	Water.	Ash.	Protein.	Fiber.	Extract Matter.	Fat.	Total.
1	H–O Company (first break), . .	4.13	8.00	9.54	23.68	50.57	4.08	100
2	H–O Company (second break), .	5.20	3.40	16.73	5.58	61.14	7.95	100
3	Quaker Oats Company, . . .	5.54	5.94	12.30	15.60	54.97	5.65	100
4	Henry & Morrison,[1] . . .	7.30	3.20	16.30	4.60	61.80	6.80	100

(*c*) *Oat Feed.*

Sample No.	Source.	Water.	Ash.	Protein.	Fiber.	Extract Matter.	Fat.	Total.
1	H–O Company, mill run, . .	4.24	6.34	6.04	26.65	54.05	2.68	100
2	Quaker Oats Company, mill run, .	5.48	5.95	5.26	27.18	53.98	2.15	100
3	Quaker Oats Company, mill run, .	5.30	6.10	4.65	26.73	55.14	2.08	100
4	Quaker Oats Company, mill run, .	9.53	5.39	5.29	24.17	53.37	2.25	100
5	Quaker Oats Company, mill run, .	7.75	5.91	5.22	24.85	54.04	2.23	100
6[2]	Quaker Oats Company, mill run, .	7.59	6.10	7.12	22.62	53.40	3.17	100
7	Quaker Oats Company, mill run, .	7.03	6.58	6.40	29.82	48.09	2.08	100
8	Quaker Oats Company, mill run, .	7.25	5.86	5.91	26.05	52.80	2.13	100
9	Quaker Oats Company, mill run, .	7.07	5.99	6.00	26.00	52.90	2.04	100
10	Quaker Oats Company, mill run, .	5.48	6.39	5.98	31.85	48.09	2.21	100
11	Quaker Oats Company, mill run, .	7.63	6.24	5.53	27.57	51.04	1.99	100
12	Quaker Oats Company, mill run, .	7.90	5.84	5.04	26.14	53.10	1.93	100
	Average, ...	6.85	6.06	5.70	26.64	52.50	2.24	100

[1] Average of 23 analyses.

[2] Sample No. 6 evidently contains an excess of middlings, and cannot be considered representative.

The results of the analyses of the two samples of oat hulls simply emphasize their very low protein and fat, — 1.49 of protein and .67 of fat, — and their very high fiber content. The fiber percentage multiplied by 3 gives 96.4 per cent of hulls, indicating the presence of very little dust or middlings.

Oat middlings vary somewhat in composition, depending naturally upon the process of separation employed. The higher the fiber content the less completely are the hulls separated. A high grade of middlings such as results from the second break evidently ought to contain not more than 5 to 6 per cent of fiber, and at least 15 per cent of protein.

The oat feed does not vary more in composition than one would expect from a by-product of this sort. Its moisture content is low, due to artificial drying, showing an average of 6.85 per cent. It has relatively little protein, extremes of from 4.65 to 7.12 being noted, with an average of 5.70 per cent. The fiber content is high, due to the large amount of oat hulls; the average percentage of fiber was 26.64. A much higher percentage of fiber than this average would indicate an excess of hulls. Carefully conducted studies[1] have shown that in case of oat by-products the percentage of fiber present multiplied by 3 will give the percentage of oat hulls. The application of this rule to the average analyses of the twelve samples (26.64 x 3 = 80) shows 80 per cent of hulls and 20 per cent of fine material (oat dust and middlings). The fat percentage in the feed is low, as would be expected.

C. Digestibility of Oat By-Products.

The station has made a number of digestion experiments with oat feed, middlings and hulls. Sheep and horses were employed for the purpose. The results only of the experiments are reported in this connection. Sheep would not eat any amount of the oat feed when fed dry, and hence it was necessary to moisten it thoroughly. It was also moistened before being fed to horses.

Table II. — *Digestion Coefficients for Oat By-Products.*

(*a*) *Oat Hulls* (*Sheep*).

Series.	Experiment.	Animal.	Percentages of Ingredients digested. Dry Matter.	Ash.	Protein.	Fiber.	Extract Matter.	Fat.	Ration Fed.
24, . . .	13	9	31	16	-	50	29	-	500 g. hay+150 g. gluten feed+150 g. oat hulls.
24, . . .	13	11	36	9	12	51	36	14	
Average, . . .			34	13	12	50	33	14	

[1] Landw. Versuchssta. Band XCIV, Heft I and II, pp. 9-40, by H. Neubauer.

TABLE II. — *Digestion Coefficients for Oat By-Products* — Concluded.

(*b*) *Oat Hulls* (*Horses*).

SERIES.	Experiment.	Animal.	PERCENTAGES OF INGREDIENTS DIGESTED. Dry Matter.	Ash.	Protein.	Fiber.	Extract Matter.	Fat.	Ration Fed.
3, ...	4	Joe	24	36	123	28	10	76	8,000 g. hay+2,500 g. brewers' grains +2,000 g. oat hulls.
3, ...	4	Tom	20	33	105	15	11	88	
Average, ...			22	34	?	22	11	82	

(*c*) *Oat Middlings* (*Sheep*).

X, ...	14	IV	91	31	81	77	97	93	550 g. hay+300 g. oat middlings.
X, ...	14	V	88	30	80	21	94	94	
Average, ...			90	36	80	49	95	93	
Wheat flour middlings for comparison.			82	–	88	36	88	86	

(*d*) *Oat Feed* (*Horses*).

3, ...	5	Joe	40	13	58	51	36	36	8,000 g. hay+2,500 g. oat feed.
3, ...	5	Tom	43	14	54	55	39	69	
Average, ...			42	14	56	53	38	53	

(*e*) *Oat Feed* (*Sheep*).

24, ...	12	12	51	92	81	39	45	119	500 g. hay+150 g. gluten feed+150 g. oat feed.
24, ...	12[1]	13	19	52	5	1	19	102	
25, ...	11[1]	9	29	–	18	23	31	185	500 g. hay+150 g. oat feed.
25, ...	11[1]	11	27	–	22	21	32	100	
25, ...	13	9	55	26	86	56	49	43	500 g. hay+150 g. gluten+150 g. oat feed.
25, ...	13	11	51	26	90	43	49	46	
25, ...	18	12	57	69	90	57	52	16	500 g. hay+150 g. oat feed.
25, ...	18	13	47	23	86	53	40	67	
Average, ...			52	–	86	46	48	69	
Timothy hay (for comparison).			55	39	47	51	62	50	
Fine hay (extra) (for comparison).			61	44	55	63	62	48	

[1] Excluded from the average.

The results with oat hulls show that the sheep were able to digest 34 per cent of the hulls, and the horses 22 per cent. The protein and fat content of the hulls is quite small, and the coefficients for these ingredients with both sheep and horses are of no particular account. The sheep digested one-half of the fiber and one-third of the extract matter, while the coefficients obtained with the horses were noticeably less. It is possible that in case of the horses, if the hulls had been fed with a different combination than hay and brewers' grains, the results would have been somewhat more favorable. It has been established, however, that horses are not able to utilize fibrous material as well as are the bovines.

The trial with oat middlings was made at this station a number of years since, and has been published.[1] The sample was found in the Massachusetts markets, and was of excellent quality, containing 16.1 per cent of protein, 2.3 per cent of fiber, and 7 per cent of fat. The results are given here to show how well the animal is able to digest oat middlings when substantially free from fiber.

TABLE III. — *Digestible Matter in 2,000 Pounds.*

(*a*) *Sheep.*

FEED.	Dry Matter.	Protein.	Fiber.	Extract Matter.	Fat.	Total Digestible Matter (Fat × 2.2).	Relative Values: Basis Digestible Matter (Oat Feed 100).
Oat hulls,	649.8	3.6	321.4	362.4	1.8	691.3	75
Oat middlings,	1,668.6	260.8	45.0	1,174.2	126.4	1,758.0	191
Oat feed,	969.6	99.0	245.4	503.6	31.4	917.7	100
Timothy hay (for comparison).	946.0	76.0	284.0	542.0	20.0	946.0	103
Fine hay (extra) (for comparison).	1,073.6	86.0	358.0	546.0	22.0	1,038.0	113

(*b*) *Horses.*

FEED.	Dry Matter.	Protein.	Fiber.	Extract Matter.	Fat.	Total Digestible Matter (Fat × 2.2).	Relative Values: Basis Digestible Matter (Oat Feed 100).
Oat feed,	782.0	64.4	282.0	338.0	24.0	737.2	100
Timothy hay,	756.8	33.6	243.4	410.8	39.4	727.2	98.6

On the basis of the digestion experiments with sheep, it will be seen that oat feed contains 918 pounds of total digestible matter as against 1,758 for oat middlings, 691 for oat hulls, and 946 for timothy hay. Placing oat feed at 100, oat middlings would have a feeding value of 91 per cent more, oat hulls 25 per cent less, and timothy 3 per cent more.

On the basis of digestible organic matter, the oat feed and timothy

[1] Mass. Agr. Expt. Sta., Ann. Rept. 19, p. 114.

appear to have about equivalent feeding values for horses. In place of digestible matter as a measurement of nutritive value, Kellner and also Armsby, as a result of more recent investigations, have adopted the unit of net energy. While recognizing its superiority over digestible matter as a basis for comparison, the writers feel that sufficient data are not available to warrant its use in the case of oat by-products.

D. Oat Feed for Dairy Cows.

Experiments I, II, and III.

In addition to the numerous analyses and digestibility trials with the several oat by-products, it was thought necessary to observe the effect of oat feed upon milk production. Inasmuch as it approximated hay in digestibility, it was fed in comparison with hay. Thus fed, a larger amount could be given daily than if used as a component of a grain mixture.

The experiments, three in number, with eight, four and eleven cows, respectively, were conducted by the usual reversal method. The basal ration consisted of a uniform grain mixture and sufficient of a first quality of cow hay to meet the needs of each animal. In each half of the experiment a definite amount of oat feed *on a dry matter basis* was substituted for a like weight of hay, amounting in case of individual cows to from 6 to 8 pounds daily. It was fed well moistened with water and was readily eaten. The average daily ration fed will be found in Table VIII.

TABLE IV. — *History of the Cows.*

EXPERIMENT I.

Name.	Age.	Breed.	Calved.	Served.	Milk Yield, Beginning (Pounds).	Fat (Per Cent).
Peggy,	9	G. Jersey,	Aug. 13, 1918	Dec. 26, 1918	18	6.4
190,	7	G. Holstein,	Dec. 3, 1918	Feb. 9, 1919	25	3.8
Colantha II,	4	G. Holstein,	July 22, 1918	Nov. 7, 1918	25	4.5
Red IV,	6	G. Jersey,	Mar. 7, 1919	– –	30	5.0
Fancy IV,	4	G. Jersey,	July 22, 1918	Oct. 30, 1918	16	5.5
Ida II,	6	P. Jersey,	Oct. 27, 1918	Feb. 13, 1919	23	6.0
Samantha III,	6	G. Holstein,	Aug. 26, 1918	Dec. 5, 1918	20	4.7
Betty II,	12	G. Ayrshire,	Jan. 24, 1919	Feb. 19, 1919	30	4.6

EXPERIMENT II.

Name.	Age.	Breed.	Calved.	Served.	Milk Yield, Beginning (Pounds).	Fat (Per Cent).
190,	8	G. Holstein,	Nov. 17, 1919	– –	31	4.4
Cecile II,	7	P. Jersey,	Oct. 12, 1919	– –	21	5.6
Ida II,	7	P. Jersey,	Nov. 22, 1919	– –	30	6.0
Peggy,	10	G. Jersey,	Oct. 9, 1919	– –	23	6.2

EXPERIMENT III.

Name.	Age.	Breed.	Calved.	Served.	Milk Yield, Beginning (Pounds).	Fat (Per Cent).
Cecile II,	7	P. Jersey,	Oct. 12, 1919	Feb. 24, 1920	18	6.2
Diantha II,	3	G. Holstein,	Jan. 22, 1920	– –	34	3.4
Colantha II,	5	G. Holstein,	Aug. 8, 1919	Nov. 3, 1919	33	4.2
Ida II,	7	P. Jersey,	Nov. 22, 1919	Feb. 10, 1919	26	6.2
Samantha III,	6	G. Holstein,	Sept. 12, 1919	Dec. 8, 1919	29	4.0
Colantha,	6	G. Holstein,	Sept. 19, 1919	Feb. 4, 1920	21	4.3
Fancy IV,	5	G. Jersey,	Aug. 10, 1919	Nov. 15, 1919	18	5.5
Eantha,	3	G. Holstein,	Jan. 19, 1919	– –	28	3.6
Samantha IV,	5	G. Holstein,	Aug. 20, 1919	Dec. 4, 1919	32	4.6
Peggy,	10	G. Jersey,	Oct. 9, 1919	Feb. 4, 1919	24	6.4
190,	8	G. Holstein,	Nov. 17, 1919	Jan. 2, 1920	31	4.4
Red IV,	6	G. Holstein,	Jan. 14, 1919	– –	32	4.9

TABLE V. — *Duration of Experiments.*

EXPERIMENT I.

Dates.	Hay Ration.	Hay and Oat Feed Ration.	Weeks Fed.
April 3, 1919, through April 30, 1919,	Fancy IV,	Peggy,	4
	Ida II,	190,	
	Samantha III,	Colantha II,	
	Betty II,	Red IV,	
May 11, 1919, through June 7, 1919,	Peggy,	Fancy IV,	4
	190,	Ida II,	
	Colantha II,	Samantha III,	
	Red IV,	Betty II,	

EXPERIMENT II.

Dec. 24, 1919, through Jan. 27, 1920,	Ida II,	190,	5
	Peggy,	Cecile II,	
Feb. 8, 1920, through March 13, 1920,	190,	Ida II,	5
	Cecile II,	Peggy,	

EXPERIMENT III.

April 1, 1920, through May 5, 1920,	Fancy IV,	Cecile II,	5
	Eantha,	Diantha II,	
	Samantha IV,	Ida II,	
	Peggy,	Samantha III,	
	190,	Colantha,	
	Red IV,	. . . . .	
May 16, 1920, through June 19, 1920,	Cecile II,	Fancy IV,	5
	Diantha II,	Eantha,	
	Ida II,	Samantha IV,	
	Samantha III,	Peggy,	
	Colantha,	190,	
		Red IV,	

Care of the Animals. — The animals were cared for in the usual way, as described in previous experiments.

Sampling Feeds and Milk. — The hay was sampled three times during each half of the trial, by taking forkfuls here and there, running the same through a power cutter, sub-sampling, and placing the sub-samples in glass-stoppered bottles which were brought to the laboratory at once, dry matter determinations made, and composite samples analyzed. The grain mixtures were sampled each time a new lot was mixed, and the samples placed in glass-stoppered bottles for analysis. The oat feed was sampled at regular intervals during the experiment.

The milk was sampled for five consecutive days for two or three weeks during each half of the trial, preserved with formalin, and analyzed for total solids and for fat by the Babcock method. The usual method of sampling was followed as described in previous experiments.

TABLE VI. — *Grain Mixtures fed (Pounds).*

Experiment I.		Experiment II.		Experiment III.	
Coconut meal,	50	Coconut meal,	40	Coconut meal,	30
Velvet bean feed,	20	Gluten feed,	30	Gluten feed,	10
Wheat bran,	20	Wheat bran,	30	Wheat bran,	20
Linseed meal,	10			Corn meal,	30
				Peanut meal,	10

Notes of the Experiment. — In Experiment I, a preliminary test of the oat feed used showed it to contain 4.95 per cent of protein and 26.89 per cent of fiber, and it was regarded as a representative lot. The final analysis, however, made from a number of different samples, gave 7.12 per cent of protein and 22.62 per cent of fiber, indicating the presence of an undue amount of oat middlings. The results of this experiment are reported, but they are not included in the average.

In Experiment III, twelve cows were employed, but during the progress of the experiment Colantha II showed such an abnormal milk shrinkage that she could not be continued, and the experiment was completed with eleven cows.

TABLE VII. — *Chemical Analysis of Feeds used (Per Cent).*

EXPERIMENT.	Feed.	Water.	Ash.	Crude Protein.	Fiber.	Extract Matter.	Fat.
I,	Hay,	10.00–11.63 10.85	5.34	7.27	26.09	47.81	2.64
	Oat feed,	7.59	6.10	7.12	22.62	53.40	3.17
	Grain mixture,	10.24	5.62	18.71	8.90	50.19	6.34
II,	Hay,	9.50–10.25 9.72	5.62	8.42	29.49	44.22	2.53
	Oat feed,	7.63	6.24	5.53	27.57	51.04	1.99
	Grain mixture,	11.08	5.64	20.90	9.10	48.24	5.04
III,	Hay,	10.96–11.96 11.46	4.23	6.98	26.70	48.08	2.55
	Oat feed,	7.90	5.84	5.04	26.14	53.10	1.93
	Grain mixture,	11.77	4.28	18.18	5.87	53.86	6.07

The hay was of good to excellent quality. It contained a considerable proportion of the finer grasses, together with some timothy and clover, and was usually cut before it was too ripe. Its fiber percentage was not unduly high, and it contained a reasonable amount of protein. Attention has already been called to the fact that the first sample of oat feed contained too large a per cent of middlings to be representative, as is indicated by its relatively low fiber and high protein and fat.

The grain mixtures contained the desired amounts of the several ingredients, and were of satisfactory composition.

A study of Table VIII shows that the average cow received the same amount of grain daily during each experiment. In case of roughage, from 6 to 8 pounds of oat feed were substituted for a like amount of hay *on a dry matter basis.* Because of the dryer condition of the oat feed, it took .5 of a pound less of oat feed in its natural condition to replace a like amount of hay, *e.g.*, 6.5 pounds of oat feed in place of 7 pounds of hay, or 8 pounds of oat feed in place of 8.5 pounds of hay, or 7.64 pounds of oat feed in place of 8.14 pounds of hay. If 8 pounds of hay in its natural state had been fed in place of 8 pounds of oat feed in its natural state the results should have been slightly more favorable to the oat feed.

TABLE VIII. — *Average Ration Consumed per Cow (Pounds).*

EXPERIMENT I.

Number of Cows.	Character of Ration.	Hay.		Oat Feed.		Grain Mixture.	
		Total per Cow.	Daily per Cow.	Total per Cow.	Daily per Cow.	Total per Cow.	Daily per Cow.
8, ...	Oat feed, . .	392.00	14.00	182.00	6.50	252.00	9.00
8, ...	Hay, . . .	588.00	21.00	–	–	252.00	9.00

EXPERIMENT II.

4, ...	Oat feed, . .	402.00	11.50	280.00	8.00	324.00	9.25
4, ...	Hay, . . .	700.00	20.00	–	–	324.00	9.25

EXPERIMENT III.

11, ...	Oat feed, . .	447.05	12.77	270.45	7.64	308.64	8.82
11, ...	Hay, . . .	731.82	20.91	–	–	308.64	8.82

TABLE IX. — *Estimated Dry and Digestible Nutrients in Average Daily Rations (Pounds).*

EXPERIMENT I.

Character of Ration.	Dry Matter.	Digestible Nutrients.					Nutritive Ratio.
		Protein.	Fiber.	Extract Matter.	Fat.	Total.	
Oat feed, ...	26.28	2.34	3.05	9.31	.86	15.57	1:6.06
Hay, ...	26.73	2.24	3.59	9.74	.77	16.34	1:6.71

EXPERIMENT II.

Oat feed, ...	25.98	2.55	3.56	8.86	.61	15.58	1:54.00
Hay, ...	26.27	2.56	4.13	9.24	.60	16.53	1:57.00

EXPERIMENT III.

Oat feed, ...	26.22	2.11	3.24	9.89	.71	15.95	1:6.96
Hay, ...	26.32	2.09	3.71	10.33	.71	16.84	1:7.52

The above figures are based upon analyses and average digestion coefficients. On this basis, in each of the three experiments, the hay ration appears to have contained a little more total digestible nutrients than the oat feed ration. The two rations in each experiment contained about the same amounts of protein and fat.

TABLE X. — *Total Yields of Milk and Milk Ingredients.*

EXPERIMENT I.

Oat Feed Ration.

Cows.	Milk produced (Pounds).	Total Solids (Per Cent).	Total Solids (Pounds).	Fat (Per Cent).	Fat (Pounds).
Peggy,	556.7	16.18	90.07	7.23	40.25
190,	747.1	12.89	96.30	4.53	33.84
Colantha II,	649.7	14.80	96.16	5.47	35.54
Red IV,	998.7	14.19	141.72	5.55	55.43
Fancy IV,	443.6	15.18	67.34	5.99	40.34
Ida II,	681.9	15.00	102.29	6.25	63.93
Samantha III,	560.0	13.92	77.95	5.08	39.60
Betty II,	848.1	13.37	113.39	4.93	55.90
Totals,	5,485.8	–	785.22	–	364.83
Averages,	–	14.31	–	6.65	–

Hay Ration.

Cows.	Milk produced (Pounds).	Total Solids (Per Cent).	Total Solids (Pounds).	Fat (Per Cent).	Fat (Pounds).
Peggy,	492.9	16.10	79.36	6.78	53.81
190,	710.2	12.75	90.55	4.39	39.75
Colantha II,	447.0	14.78	66.07	5.44	35.94
Red IV,	860.6	13.39	115.23	5.50	63.38
Fancy IV,	455.2	15.43	70.24	5.93	26.99
Ida II,	695.1	15.35	106.70	6.24	43.37
Samantha III,	591.7	14.21	84.08	5.32	31.48
Betty II,	884.0	13.78	121.82	4.93	43.58
Totals,	5,136.7	–	734.05	–	338.30
Averages,	–	14.29	–	6.58	–

TABLE X. — *Total Yields of Milk and Milk Ingredients* — Continued.

EXPERIMENT II.

Oat Feed Ration.

Cows.	Milk produced (Pounds).	Total Solids (Per Cent).	Total Solids (Pounds).	Fat (Per Cent).	Fat (Pounds).
190,	1,115.4	12.53	139.76	4.33	48.30
Cecile II,	695.1	14.79	105.59	5.86	41.83
Ida II,	877.2	14.85	130.26	6.00	52.63
Peggy,	806.0	15.12	121.88	6.43	51.83
Totals,	3,512.6	–	497.49	–	194.59
Averages,	–	14.16	–	5.54	–

Hay Ration.

Cows.	Milk produced (Pounds).	Total Solids (Per Cent).	Total Solids (Pounds).	Fat (Per Cent).	Fat (Pounds).
190,	1,060.9	12.66	134.31	4.25	45.09
Cecile II,	640.6	15.33	98.20	6.24	39.97
Ida II,	973.6	14.93	145.36	6.09	59.29
Peggy,	799.3	15.17	121.25	6.50	51.95
Totals,	3,474.34	–	499.12	–	196.30
Averages,	–	14.37	–	5.65	–

EXPERIMENT III.

Oat Feed Ration.

Cows.	Milk produced (Pounds).	Total Solids (Per Cent).	Total Solids (Pounds).	Fat (Per Cent).	Fat (Pounds).
Cecile II,	612.0	15.37	94.06	6.37	38.98
Diantha II,	1,164.5	12.11	141.02	3.88	45.18
Ida II,	858.9	14.92	128.15	6.03	51.79
Samantha III,	873.3	13.26	115.80	4.70	41.05
Colantha,	802.7	12.78	102.59	4.50	36.12
Fancy IV,	586.0	14.83	86.90	5.65	33.11
Eantha,	833.5	12.53	104.44	4.07	33.92
Samantha IV,	963.2	13.25	127.62	4.84	46.62
Peggy,	757.7	15.19	115.09	6.30	47.74
190,	915.4	13.05	119.46	4.44	40.64
Red IV,	1,009.6	14.45	145.89	5.60	56.54
Totals,	9,376.8	–	1,281.02	–	471.69
Averages,	–	13.66	–	5.03	–

TABLE X. — *Total Yields of Milk and Milk Ingredients* — Concluded.

EXPERIMENT III — *Concluded.*

Hay Ration.

Cows.	Milk produced (Pounds).	Total Solids (Per Cent).	Total Solids (Pounds).	Fat (Per Cent).	Fat (Pounds).
Cecile II,	583.6	15.22	88.82	6.07	35.42
Diantha II,	1,081.1	11.67	126.16	3.52	38.05
Ida II,	791.9	14.43	114.27	5.54	43.87
Samantha III,	597.9	13.79	82.45	5.01	29.95
Colantha,	724.5	12.71	92.08	4.74	34.34
Fancy IV,	606.0	14.98	90.78	5.88	35.63
Eantha,	853.1	12.58	107.32	4.23	36.09
Samantha IV,	1,047.3	13.30	139.29	4.76	49.85
Peggy,	744.3	15.29	113.80	6.59	49.05
190,	967.3	13.08	126.52	4.52	43.72
Red IV,	1,029.5	14.04	144.54	5.56	57.24
Totals,	9,026.5	-	1,226.03	-	453.21
Averages,	-	13.58	-	5.02	-

TABLE XI. — *Summary of Yields (Pounds).*

EXPERIMENT.	Character of Ration.	Number of Cows.	Milk produced.	Total Solids.	Total Fat.
I,	Oat feed,	8	5,485.8	785.22	364.83
	Hay,		5,136.7	734.05	338.30
II,	Oat feed,	4	3,512.6	497.49	194.59
	Hay,		3,474.3	499.12	196.30
III,	Oat feed,	11	9,376.8	1,281.02	471.69
	Hay,		9,026.5	1,226.03	453.21
Totals, II and III,	Oat feed,	15	12,889.4	1,778.51	666.28
	Hay,		12,500.8	1,725.15	649.51

TABLE XII. — *Percentage Increase Oat Feed Over Hay.*

Experiment.	Milk produced.	Total Solids.	Total Fat.
I,	6.7	7.0	7.8
II,	1.1	–	0.9
III,	3.9	4.5	4.1
Totals, II and III,	3.1	3.0	2.5

The results of Experiment I have been omitted from the average because of the variation of the lot of oat feed from the recognized standard. The results of Experiments II and III with four and eleven cows, respectively, covering periods of five weeks each, show that the substitution of from 7 to 8 pounds of dry matter in the form of oat feed for a like amount of dry matter in the form of a good quality of hay (8 pounds and 7.64 pounds of oat feed in place of 8.5 pounds and 8.14 pounds of hay in natural condition) produced substantially 3 per cent more milk and milk ingredients.

TABLE XIII. — *Gain or Loss in Live Weight (Pounds).*

Experiment.	Gain.		Loss.		Net.	
	Oat Feed Ration.	Hay Ration.	Oat Feed Ration.	Hay Ration.	Oat Feed Ration.	Hay Ration.
I,	79	38	56	78	23+	40–
II,	12	15	47	53	35–	38–
III,	231	180	37	50	194+	130+
Averages, II and III,	–	–	–	–	159+	92+

During the experiments the cows on the two different rations showed little change in weight. Our object in each experiment was to feed them a little less than was required for maintenance and milk yield, in order to get, so far as possible, the full effect of each ration. In Experiment III some of the cows were considerably advanced in lactation, at which time they are prone to increase somewhat in weight.

E. Oat Feed for Horses.

Oat feed has been fed to a pair of farm horses, Joe and Chub, at intervals for a period of five months, beginning in early May. The horses had been used for digestion work during the winter, and it was necessary during the early spring to bring them on to a full day's work by degrees. They were employed in plowing, harrowing, drawing manure, mowing, and in similar work for nine hours daily during five and one-half days in each week.

The oat feed was substituted for the hay, at first in the proportion of 5 pounds, and later 6 pounds, daily.

The "grain mixture" consisted of 10 pounds of cracked corn, 1 pound of wheat bran, and 1 pound of cottonseed meal. The object of feeding the cottonseed was to furnish some extra protein in the ration, and to note if any objectionable effect occurred from its use. The wheat bran was used not only for its nutritive value, but because of its gentle laxative effect.

Table XIV. — *Daily Rations consumed (Pounds).*

Periods.	Joe.				Chub.			
	Grain Mixture.	Whole Oats.	Hay.	Oat Feed.	Grain Mixture.	Whole Oats.	Hay.	Oat Feed.
May 3–June 13,	12	5	15	–	11	5	9	5
June 14–July 11,	12	5	10	5	11	5	14	–
July 12–August 8,	12	5	15	–	11	5	8	6
August 9–September 12,	12	5	9	6	11	6	14	–

The table shows that each horse received daily 12 and 11 pounds, respectively, of the grain mixture of corn, cottonseed and bran. This amount was divided into two feeds, and given in the morning and evening. At noon each horse received 5 pounds of oats. From May 3 to June 13, inclusive, Joe received daily 15 pounds of hay and no oat feed, while Chub received 9 pounds of hay and 5 pounds of oat feed. From June 14 to July 11, inclusive, the conditions for the coarse feed were reversed, Joe receiving the hay and oat feed and Chub the hay only. Conditions were again reversed July 12–August 8, and again August 9–September 12, so that during each period from May 1 through September 12 one of the horses was receiving hay for roughage and the other a limited amount of hay and 5 or 6 pounds daily of the oat feed. The latter was well moistened before being fed, and given in three portions. The horses objected a little to the oat feed at first, but soon learned to eat it readily.

TABLE XV. — *Estimated Digestible Nutrients consumed Daily (Pounds).*

RATION FED.	Protein.	Total (Fat × 2.2).	Nutritive Ratio.
15 pounds hay, 5 pounds oats, 10 pounds cracked corn, 1 pound cottonseed meal, 1 pound wheat bran.	2.40	20.20	1:7.4
9 pounds hay, 6 pounds oat feed, 5 pounds whole oats, 10 pounds cracked corn, 1 pound cottonseed meal, 1 pound wheat bran.	2.30	19.50	1:7.5
Standards for comparison: —			
Kellner's (moderate work), ...	2.00	17.70	1:8.0
Kellner's (hard work), ...	2.80	24.50	1:7.7
Lavalard's (moderate work), ...	1.86	18.10	1:8.3
Grandeau's (moderate work), ...	2.20	17.96	1:7.9

The horses approximated 1,400 pounds each in weight. The above figures show the estimated digestible nutrients that were fed daily and the standard requirements for horses weighing 1,400 pounds, as stated by different authorities. It seems clear that the horses, which were doing moderately hard work, were receiving sufficient digestible protein and total nutrients. It is doubtful if they would have kept in good condition with less food.

TABLE XVI. — *Weights of Animals.*

Joe.

DATES.	Weeks.	Character of Ration.	Weight, Beginning.	Weight, End.	Gain or Loss.
May 3–June 13, ...	6	Hay, . .	1,430	1,410	20—
June 14–July 11, ...	4	Hay-oat feed, .	1,410	1,435	25+
July 12–August 8, ...	4	Hay, . .	1,435	1,425	10—
August 9–September 12, . .	5	Hay-oat feed, .	1,425	1,440	15+

Chub.

DATES.	Weeks.	Character of Ration.	Weight, Beginning.	Weight, End.	Gain or Loss.
May 3–June 13, ...	6	Hay-oat feed, .	1,370	1,350	20—
June 14–July 11, ...	4	Hay, . .	1,350	1,375	25+
July 12–August 8, ...	4	Hay-oat feed, .	1,375	1,390	15+
August 9–September 12, . .	5	Hay, . .	1,390	1,430	40+

General Effect of the Ration.

The animals were weighed weekly, and minor variations were noted. Weights at the beginning and end of the change of ration are here given. The weights indicate that Joe evidently was receiving sufficient food to keep him in equilibrium and to enable him to do his work in a satisfactory way, while Chub was receiving a little more than was necessary. The latter was shorter of leg and chunkier in build, and would be termed an easy keeper. During the first period of six weeks (May 3–June 13) both horses lost a little in weight, due to the work required after a winter of comparative inaction. In the second period of four weeks (June 14–July 11) each horse gained 25 pounds irrespective of the ration, due probably to the less amount of work performed. During the third period of four weeks (July 12–August 8) Joe on the hay ration lost 10 pounds, and Chub on the hay-oat feed ration gained 15 pounds, while in the last period of five weeks both horses gained somewhat, probably because of the less strenuous character of the daily work requirements.

Summary and Discussion.

The term "oat feed" does not refer to ground oat hulls, but to the so-called "mill run" resulting from the first milling of oats. The product from the large modern mills contains some 80 per cent of hulls and 20 per cent of middlings and dust. Because of the finely ground condition of the hulls as placed upon the market it is not possible to separate the hulls from the middlings by mechanical means. An average quality of oat feed contains 5 to 6 per cent of protein, about 2 per cent of fat, and not over 27 per cent of fiber. Less protein and fat and more fiber indicate an excess of hulls, while more protein and fat and less fiber show an extra amount of middlings, and consequently a superior product.

While in digestibility oat feed falls a little below hay, feeding trials with dairy cows have shown it to be slightly superior in the production of milk.

In case of horses, the feeding of 5 to 6 pounds daily of oat feed in place of a like amount of hay was productive of quite satisfactory results, and no disturbances of any kind were noted during the four and a half months of the trial. It may be possible to substitute more than 6 pounds of oat feed for a like amount of hay, but we should hardly advise it, both because of its lack of palatability and its lack of bulk as compared with hay. The feeding of 1 pound of cottonseed meal daily in the grain mixture was in no way injurious, so far as we were able to observe, and it is believed that the extra protein furnished had a favorable effect upon the animals.

The writers are of the opinion that oat feed, if placed upon the market unmixed, can best be used pound for pound as a partial hay substitute for dairy cows, young stock, fattening cattle and horses, providing the supply of hay is limited and oat feed can be bought at a reasonable price.

From 6 to 8 pounds daily can thus be fed (well moistened) to mature bovines, proportionately less to young stock, and about 5 to 6 pounds daily to horses.

While oat feed is used in considerable amounts in many proprietary grain mixtures, the best grades, whether rich in protein or carbohydrates, cannot contain large quantities for the reason that such an addition would unduly increase their fiber content and also lessen their digestibility.

The claim is made that aside from its nutritive value, oat feed possesses merit as bulk, serving to distribute and lighten the heavier concentrates. How valid this claim is has not been proved, although as a result of experience many feeders claim that the feeding of considerable amounts of a grain ration which lacks bulk is not advisable. Be that as it may, the use of a few hundred pounds (about 15 per cent) of oat feed in a ton of home-mixed ration would not be objectionable, especially if the other ingredients are highly digestible and finely ground.

In view of the ever-increasing demand for the grains as human food, it should be the aim of both the manufacturer and feeder to use the by-products to the best advantage. Methods for improving the digestibility of indigestible materials, such as grain hulls and the like, merit the careful attention of investigators.

Oat feed should bear a guarantee of composition, and the manufacturers should be careful that it is of stable composition. The purchaser will lose confidence if it shows variations from an accepted standard, or if material is offered as oat feed which consists only of ground oat hulls.

Low-grade by-products, of which oat feed is a type, must be *sold on their merits* and at a price commensurate with their feeding value. Any attempt to sell such material either by itself or in proprietary mixtures at prices unwarranted by its feeding value as compared with feeding stuffs of higher grade would quickly destroy the confidence of the purchaser and result in a slackened demand for the article. The old motto of "state what you sell and sell what you state" may be improved by the addition of the clause "at a price commensurate with its value," and would be especially applicable to this class of materials.

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